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Operational Evaluation of the Converging Runway Display Aid at St. Louis

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16. Abstract

This report describes the evaluation of the Converging Runway Display Aid (CRDA) which has been used in an operational environment at Lambert-St. Louis International Airport since December 1990. The intent of the evaluation has been to determine the operational benefits of using CRDA at St. Louis and to assess the operational suitability of the aid for national implementation at those airports which have converging or intersecting runway configurations. As a result of the evaluation, it was determined that the CRDA computer/human interface is operationally suitable, use of CRDA can increase airport capacity, with the DCIA procedures provides an acceptable margin of safety. This report supports the decision to proceed with the national implementation of CRDA and provides guidance material for potential users of the aid.

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PREFACE

This document describes a four-phased evaluation of the use of the Converging Runway Display Aid (CRDA) at Lambert-St. Louis International Airport. It was originally expected that enough operations would have been conducted by this point in time to complete the evaluation. However, as described in section 5.4, the appropriate weather conditions necessary to complete the evaluation have not occurred. St. Louis still needs to conduct more operations during very poor weather conditions in order for the evaluation to be completed. While waiting for those specific weather conditions, however, the operations conducted to date have enabled almost all of the evaluation objectives to be met. Those results are documented in this report. Following the technical completion of the CRDA evaluation, another appendix to this report will be published that documents those final operations and any additional findings or recommendations.

ACKNOWLEDGMENTS

The evaluation of the Converging Runway Display Aid (CRDA) at St. Louis, and the production of this report, would not have been possible without the assistance of many people within the Federal Aviation Administration and at MITRE. While it is not possible to acknowledge the many significant contributors individually, the authors would like to express their appreciation for the cooperation and teamwork that made the St. Louis evaluation a success.

Our thanks go to FAA Headquarters personnel for managing the project and coordinating all aspects of the evaluation. The evaluation of CRDA at St. Louis was truly a joint ARD/AAT effort. The teamwork between ARD and AAT was an important factor to the success of the CRDA evaluation. This teamwork on the St. Louis evaluation, in turn, paved the way for the subsequent national implementation of CRDA.

FAA Technical Center personnel coordinated with St. Louis on the installation of any new hardware or software required to complete the evaluation. FAA Central Region personnel contributed significantly to the success of the project, specifically in the suggestion of the "step down" criteria for evaluating the stagger function.

Nearly everyone at the St. Louis facility contributed to the evaluation of CRDA -- facility management, Terminal Radar Approach Control Facility controllers and Traffic Management Coordinators, tower controllers, members of the Plans and Procedures (P&P) Staff and the Automation Staff, and facility and P&P staff secretaries. David Lister of the P&P Staff was involved in all aspects of the evaluation process and was a key contributor to development of the waiver that was required to allow the evaluation to take place at St. Louis. The authors would also like to thank
Joe Snyder, Chuck Peacock, and Gene DeWeese for providing backup support and interim leadership at St. Louis when there were personnel changes, thus providing project continuity that was essential to success of the evaluation. Keith Reeves provided automation support for making the required changes to the CRDA code and adaptation, and made data tapes available for analysis. Our thanks also go to Roy O' Conner, Assistant Manager for Plans and Procedures, for providing the necessary management oversight and for adding a good sense of operational perspective throughout the evaluation. The support of the St. Louis Facility Chiefs, Larry Gray and Joe Hokit (who succeeded Larry), was especially appreciated.

Just as the CRDA evaluation at St. Louis called for teamwork within the FAA, so it went at MITRE. The managers and technical staff members working the CRDA project at MITRE, even when they were at times under schedule pressures to support other activities of the project (CRDA field site surveys, missed approach simulation and analysis, etc.), never failed to respond to a call fc- help in supporting the St. Louis evaluation. Kerry Levin provided

department-level management of the project, and lent an understanding ear when the going at times got tough. He also provided much needed management support to get over some high hurdles. Day-to-day project management at MITRE was the responsibility of Art Smith. Art not only filled that role, but also rolled up his sleeves and pitched in as one of the team. The authors are grateful to Art, Jennifer Levin Harding, David Barker, Anand Mundra, and Jim Winters (formerly of MITRE) for their unfailing support in (1) visiting St. Louis to observe and collect data on CRDA operations, (2) planning and participating in the live missed approach flight demonstration at St. Louis, and (3) reducing and analyzing data collected at St. Louis. Special thanks also go to Art, Anand, and David for the extensive missed approach analysis and briefings that were necessary to obtain the test waiver for the evaluation. The authors are really proud to have been part of this team that always "went the extra mile."

Finally, we would like to thank Chris Moody, the MITRE peer reviewer of this document, whose constructive criticism made this a better report.

EXECUTIVE SUMMARY

1.0 INTRODUCTION

1.1 PURPOSE

During the period December 1990 through publication of this report, the Converging Runway Display Aid (CRDA), an automation aid for terminal air traffic controllers intended to enhance airport capacity, was demonstrated at Lambert-St. Louis International Airport. This report documents the evaluation of that operational demonstration. The intent of the evaluation was to determine the operational benefits of using CRDA at St. Louis, and to assess the operational suitability of the CRDA as a step toward possible national implementation of the aid at selected airports which have converging or intersecting runway configurations.

The purpose of this report is to:

- Describe the evaluation method used
- Describe the results of the operational evaluation
- Document lessons learned during the evaluation at St. Louis and other CRDA-related activities, to provide guidance for the implementation of the CRDA at other sites

The information contained in this document is intended to be of use to the following organizations:

- Those Federal Aviation Administration Headquarters organizations which were responsible for deciding to implement CRDA nationally
- Those facilities that are considering introducing CRDA into their operations
- Those organizations which are generally cognizant of Air Traffic Control (ATC) capacity issues and planned system improvements for increasing capacity

1.2 BACKGROUND

During Visual Meteorological Conditions (VMC), air traffic controllers use visual procedures that allow operation on multiple runways simultaneously. However, during Instrument Meteorological Conditions (IMC) some runways cannot be used concurrently. The consequent erosion of airport capacity in IMC is the single most important cause of delays in the U.S. air traffic system. The conduct of staggered approaches to converging runways in

IMC is one means of obtaining a needed increase in airport capacity by permitting the safe use of multiple runways concurrently, even when weather conditions do not permit visual approaches.

Dependent Converging Instrument Approaches (DCIA) is a national program developed to increase airport capacity in IMC for those airports with converging or intersecting runways. The DCIA procedure permits controllers to provide minimum staggered separation on approaches to converging runways, while protecting against separation violations due to possible consecutive missed approaches. It is difficult, however, for controllers utilizing the DCIA to stagger aircraft precisely, especially on a sustained basis, without some type of visual controller aid.

The MITRE Corporation developed a concept for an automation aid -- known as the CRDA -- which could be used to assist air traffic controllers in maintaining the stagger distances established between aircraft at the runway thresholds using DCIA. In addition, the aid could be used for other operations, in either VMC or IMC, in which the distance relationship between aircraft on converging approaches is important to the safe and efficient utilization of the airspace and the airport. The basic function of the CRDA is to project position information (known as "ghost" targets) and associated alphanumeric data for aircraft on approach to one runway of the converging runway pair onto the final approach course of the other runway of the pair; thus enabling the controller to make better judgments regarding spatial relationships between aircraft approaching the converging runways.

During Fiscal Year (FY) 1989, MITRE developed a laboratory simulation of the CRDA (also known as the "ghosting aid") for a St. Louis operational environment, and conducted experiments with controllers from the St. Louis Terminal Radar Approach Control Facility to determine the utility of the aid and to identify desired design modifications. The experiments consisted of several phases, and the design of the aid evolved to reflect feedback from the St. Louis controllers. By the summer of 1989, the FAA, including St. Louis, considered the simulated CRDA version to be an effective aid for conducting staggered approaches for converging runways. Additionally, the St. Louis controllers identified an application of the aid -- known as "tieing" -- which applies during VMC conditions at St. Louis.

In parallel with the MITRE laboratory simulations, a test National Airspace System (NAS) Change Proposal (NCP) was developed, coordinated, and approved. The NCP called for St. Louis to use CRDA in a operational environment. The aid was to be evaluated under a DCIA test waiver permitting staggered approaches in IMC . The results of the laboratory simulation were used to develop a functional specification of the aid for incorporation into Automated Radar Terminal System IIIA at St. Louis. Development and testing of the aid was conducted at the FAA Technical Center (FAATC). In parallel with software development at the FAATC, extensive simulation testing was performed by MITRE to assure that adequate spatial and time separations would be provided for a variety of situations in the unlikely case that consecutive missed approaches were to be executed.

After delivery of CRDA to St. Louis in ARTS IIIA, and completion of site acceptance testing, the operational evaluation of the CRDA, as reported in this document, commenced.

2.0 GENERAL USES OF THE CRDA AT ST. LOUIS

To best understand the objectives and results of the evaluation of CRDA operations at St. Louis, it is important to have an understanding of the ways in which CRDA was operationally used at St. Louis. The CRDA was used in two modes of operation at Lambert-St. Louis International Airport. In the first mode -- known as staggering -- the aid was used in IMC in order to improve arrival throughput; in the second mode -- known as tieing -- the aid was used in VMC and marginal IMC to improve both arrival and departure throughput. The principal area of interest during the evaluation was the stagger mode of operation, since use of this mode in IMC is expected to provide the greatest capacity benefits at selected airports with converging or intersecting runway operations. Figure ES-1 depicts the layout of Lambert-St. Louis International Airport, and the following sections describe the two modes of operation.

2.1 STAGGER OPERATION

Prior to obtaining a waiver to conduct DCIA procedures and implementing CRDA, when ceiling and/or visibility conditions precluded the simultaneous use of the parallel runways 30R and 30L, St. Louis would use staggered approaches to converging runways 30R and 24 until the ceiling and visibility dropped to values such that the local controller could not acquire aircraft visually before losing 3 nautical miles (nmi) lateral separation between aircraft on the converging secondary stream. In practice, this meant that the local controller had to visually acquire the aircraft for runway 24 by the time it was about 2 nmi from the threshold, and this in turn is usually achievable down to a ceiling of about 800 feet. When meteorological conditions degraded below this point, converging approaches were discontinued and a single arrival stream was used to runways 30R/30L. When a single arrival stream must be used, the usual acceptance rate for the airport is 36 aircraft per hour.

The test waiver for St. Louis permitted staggered dependent converging instrument approaches to runways 30R and 24 during Instrument Flight Rule (IFR) conditions down to Category (CAT) I minima as long as a minimum stagger of 2 nmi was provided between successive arrivals on the converging approach paths, or a 5 nmi stagger if the leading aircraft was a heavy.[1] In this mode of operation, departures would use runway 30L.

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1 A stagger distance of R nmi between a pair of aircraft approaching converging runways means that when the lead aircraft is at its runway threshold, the trailing aircraft should have R more miles to the intersction of the converging runways than does the lead aircraft.

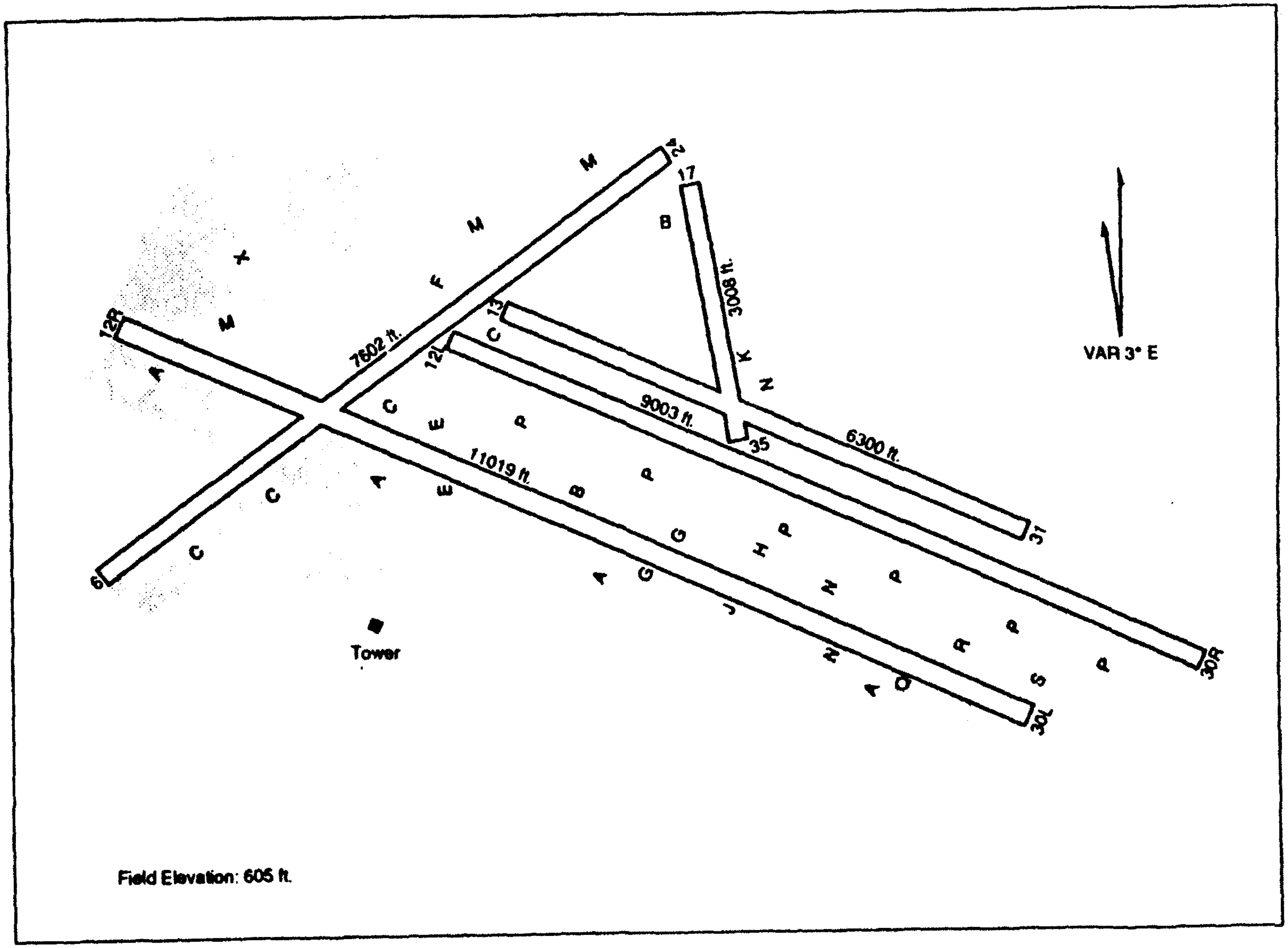

Figure ES-1. Layout of Lambert-St. Louis International Airport

When CRDA is used to support DCIA in the stagger mode, data on aircraft approaching 30R is projected (i.e.,"ghosted") and displayed at the control position of the runway 24 final approach controller, and data on runway 24 arrivals is ghosted to the 30R final approach control position. This data consists of a ghost position symbol, an optional line of data containing a coast indicator (if applicable), a heavy jet indicator (if applicable) and/or ground speed; a leader line is also displayed if the optional line of data is displayed. The control positions for the 30R and 24 final approach controllers were physically adjacent during stagger operations so as to facilitate verbal coordination between the two controllers. The controllers used the data provided by the aid, and coordinated between themselves, to separate the approaching aircraft in order to achieve the required stagger distances. The expectation was that use of this dependent stagger operation would permit St. Louis to land more than 36 aircraft an hour in IMC conditions down to CAT I.

2.2 TIEING OPERATION

In Visual Flight Rules (VFR) conditions and when landing to the west and south, St. Louis can achieve its maximum arrival throughput when runways 24, 30R and 30L are all used simultaneously for arrivals. Before the introduction of CRDA, however, St. Louis often had to discontinue landings on runway 24 as traffic demand increased due to a dependency between runway 24 arrivals and runway 30R departures. Note from figure ES-1 that since the flight path for 30R departures intersects the flight path of the 24 arrivals, arrival and departure operations on these two runways need to be coordinated.

The operational solution applied to this problem is for the controllers to attempt to "tie" arrivals on 30R and 24; that is, to have the 30R arrival reach the runway threshold at about the same time that the runway 24 arrival reaches the runway 24 threshold. If this can be accomplished, then while the 30R arrival is taxing off the runway, the 24 arrival will have taxied off the runway or will have rolled past the 24/30R intersection point (i.e., the point at which 24 and 30R would intersect if 30R were extended). If the next departure on 30R is instructed by the local controller to "position and hold" on runway 30R as soon as the 30R arrival touches down, and is released for takeoff as soon as the 30R arrival clears the runway, then there is a natural gap in the 24 arrival stream (due to standard longitudinal separation standards) which permits the 30R departure to takeoff and clear the intersection with adequate separation. Tieing arrivals reduces "dead time" and maximizes the number of 30R departures which can be achieved during triple runway arrival operations. The problem in pre-CRDA operations was that the controllers were not able to achieve satisfactory ties on a sustained basis because it was difficult to maintain a mental picture of the spatial and timing relationships between the aircraft on the converging streams; and attempting to do so during heavy traffic conditions had an adverse impact on the controllers' ability to perform other control tasks. The net effect was that arrival operations to runway 24 often needed to be discontinued in order to accommodate the release of departures.

The CRDA provides visual assistance to the controllers in performing the tie operation. In this mode of operation, aircraft approaching runway 30R are ghosted to the runway 24 final approach control position. The data presented to the controller in the ghost data block is the same as that provided during staggering operations. The runway 24 approach controller uses the ghost data by attempting to superimpose the position of an actual runway 24 arrival onto, or slightly behind, the ghost of the corresponding 30R arrival. The controller accomplishes this by issuing speed and vector control commands to aircraft approaching runway 24 in order to cause the tieing of the 24 and 30R arrivals. The local controller in the tower makes the final decision as to whether the tie was good enough to permit a departure on 30R.

3.0 OBJECTIVES OF THE EVALUATION OF CRDA OPERATIONS

The principal objectives of the evaluation of using DCIAs and CRDA, in an operational environment at St. Louis, can be stated in terms of a series of high-level questions from the following perspectives:

-- From the viewpoint of airport operations, (a) does the aid provide an operational benefit to the facility?; (b) how can the aid best be used to facilitate St. Louis operations?; and (c) what can be learned at St. Louis to support the implementation of the aid at other facilities during national implementation?

-- *From the viewpoint of the controller* (TRACON and tower controllers), does the aid need to be modified prior to national implementation to improve its utility in an operational environment? If so, how?

-- From the viewpoint of IFR procedures (i.e., DCIA) to be used with the aid, do the proposed IFR procedures assure that an adequate margin of safety is provided when the aid is used to conduct staggered, converging approaches in IFR?

Each of these high-level questions was broken down into more specific questions to guide and focus the operational evaluation at St. Louis.

4.0 APPROACH TO THE OPERATIONAL EVALUATION

Prior to using CRDA in an operational environment, a significant amount of shakedown and functional verification testing was conducted at the FAA Technical Center. This testing served to reassure Air Traffic Services about the feasibility of going ahead with the CRDA "proof of concept" at St. Louis. As a further precaution, a preliminary evaluation of the CRDA Computer/Human Interface (CHI) was performed, during Phase I, in the Enhanced Target Generator (ETG) laboratory at St. Louis, before the aid was allowed to be used operationally.

The evaluation of the CRDA at St. Louis was performed in an operational environment. That is, after suitable training, the aid was used in air traffic operations by the TRACON and tower controllers, and the evaluation was conducted in that context. Hereafter, this evaluation of the running of CRDA in a operational environment at St. Louis will be referred to as the "operational evaluation" of the DCIA procedures and CRDA aid.

The overall St. Louis plan for the use and evaluation of the aid called for all TRACON and tower controllers to be trained in the use of the aid, with the entire controller complement progressing through the various phases of the evaluation as a single "class" (see below for a description of the phases). The goal was for all controllers to be brought to an equivalent level of training and operational proficiency with the aid before advancing together to the next phase of the operational evaluation. This approach was chosen to simplify training and the evaluation process, and to facilitate the gradual, orderly transitioning of the aid into full-scale operations at St. Louis.

The operational evaluation was conducted in two ways. The formal portion of the evaluation consisted of the minimum essential steps required to fully and formally evaluate the use of the aid at St. Louis. The formal evaluation was the principal basis of this report on the results of the St. Louis operational evaluation. The formal evaluation process consisted of: (1) the use of questionnaires to elicit controller views on the CHI; (2) the conduct of evaluation periods during which observers were positioned at key locations and completed evaluation logs, noting significant events; (3) the collection of quantitative ARTS data on magnetic tape for purposes of obtaining objective evaluation data such as arrival throughput; (4) the conduct of structured controller group debriefings; and (5) the conduct of periodic Project Management Reviews (PMRs) and Operational Readiness Reviews (ORRs).

The formal evaluation was augmented by an informal, day-to-day evaluation. The informal evaluation consisted of both visual observations by non-controller personnel and manual logs maintained in both the tower and the TRACON. The informal evaluation was a principal input in determining the required extent of the formal evaluation. Findings from the informal evaluation were primarily reported and discussed during weekly project telephone conferences. Those weekly telephone conferences were added to the original evaluation plan by the project team as a result of an unforeseen schedule slip following Phase II, in an attempt to prevent future schedule problems.

The operational evaluation proceeded in four phases. As mentioned earlier, the entire complement of TRACON and tower controllers moved from one phase to the next as a single group. The decision to proceed to the next phase included consideration of factors such as (1) whether all controllers had been sufficiently trained and had achieved a suitable level of proficiency in operational use of the aid during the previous phase, (2) whether related operational procedures had been validated or refined as necessary, and (3) whether the formal evaluation planned for the previous phase had been completed satisfactorily.

Phase I of the operational evaluation involved training controllers and supervisors in the use of the aid, for both tieing and stagger operations. Such training consisted of classroom training and hands-on training with the ETG.

After the completion of training, Phase II commenced with the aid being used in actual operations to perform tieing during VFR and marginal IFR conditions. This approach was expected to provide St. Louis with an early benefit from the use of the aid.

Phase III of the operational evaluation consisted of using the aid to perform stagger operations in VFR conditions. Although the stagger aid would normally be used in IFR conditions, this phase was included in order to provide opportunities for the controllers to become proficient in the use of the stagger application of CRDA before proceeding to use in actual IFR conditions.

The last formal phase of the St. Louis operational evaluation -- Phase IV -- consisted of using the aid to support staggering operations in IFR conditions. During this phase, the IFR procedures developed under the test waiver for St. Louis were used, and a monitor controller was stationed in the tower to ensure that at least minimum separation was provided between aircraft executing converging approaches. As mentioned in section 2, use of the aid in this mode of operation was expected to result in arrival throughput gains at St. Louis.

5.0 CONDUCT OF THE CRDA OPERATIONAL EVALUATION

This section will summarize the highlights of each phase of the operational evaluation. A summary of the conclusions drawn from the operational evaluation is presented in section 6.

5.1 PHASE I: CRDA TRAINING

Proper training was considered critical to successful implementation of the CRDA at St. Louis. Although the controllers at St. Louis had previously used manual tieing and stagger techniques with arrivals to the converging runways, the display of a ghost target was new to them. Potential controller concerns with CRDA as an automation aid needed to be addressed. The controllers had to develop a high level of confidence in the accuracy of the computer-generated ghost target, before it could be used in actual operations. Further, the training phase needed to address controller concerns regarding whether there would be sufficient separation at the intersection in the case of consecutive missed approaches during stagger operations.

CRDA training consisted of technical briefings for all controllers and supervisors, as well as hands-on ETG experience for the TRACON controllers and supervisors, and ETG demonstrations for the tower personnel. This was accomplished by having each controller

first attend a detailed briefing on tieing and staggering, followed by a period of questions and answers intended to resolve any controller uncertainties about the aid. Following the briefing, each TRACON controller received experience in the ETG Lab handling simulated aircraft while running both tieing and staggering operations.

During this phase of the evaluation, the training program itself was evaluated, and a preliminary evaluation of the CRDA CHI was performed.

5.2 PHASE II: CRDA TIEING OPERATIONS

The principal objectives of Phase II of the CRDA operational evaluation were to determine (1) the suitability of the CHI in conducting tieing operations, (2) the ability of the controllers to achieve effective ties with the aid, and (3) the impact of effective tieing on St. Louis operations. Controller questionnaires, structured controller group debriefings, and project management reviews were used to determine how well these objectives were being met throughout this phase.

Due to decreased air traffic levels throughout this phase of the evaluation (primarily a result of an economic recession in the United States and the Persian Gulf War), less controller experience with the CRDA tieing aid was gained than originally expected. However, sufficient experience was gained with CRDA tieing to successfully complete this phase of the evaluation. Further, CRDA-assisted tieing operations continued to be evaluated after the formal conclusion of this part of the evaluation.

5.3 PHASE III: CRDA STAGGER OPERATIONS IN VFR

The principal objective of Phase III of the evaluation was to provide an opportunity for St. Louis controllers to obtain adequate experience in stagger operations during VFR conditions when the tower could provide visual separation prior to the loss of standard radar separation.

It was difficult to meet this objective in Phase III primarily due to the fact that use of IFR-based separation standards during VFR conditions generally led to intolerable user delays. This approach was therefore abandoned and several safety-related initiatives were undertaken by the FAA to assure that it was safe to proceed to Phase IV. These initiatives included the conduct of extensive simulation analysis of consecutive missed approaches at St. Louis, the conduct of a limited live flight demonstration of consecutive missed approaches at St. Louis in VFR conditions, and others. Phase III culminated in a successful CRDA Users Conference held in Washington, D.C., and the subsequent signing of the test waiver permitting St. Louis to proceed to CRDA-assisted stagger operations in IFR.

5.4 PHASE IV: CRDA STAGGER OPERATIONS IN IFR

There were five objectives to be met by the Phase IV evaluation, several of which were originally planned for Phase III, but were deferred to Phase IV. Although the Phase IV evaluation will not have been completed prior to the publication of this report, what has been learned so far (via the formal and informal evaluations) satisfies all but one of those objectives. The five objectives of this phase of the evaluation were:

- Determine the suitability of the CRDA CHI and related procedures
- Assess the ability of the controllers to achieve consistent, accurate staggers
- Assess whether staggering provides an arrival throughput increase, and, if so, the magnitude of the increase
- Assess the impact of staggering on departure operations
- Assess the need for a CRDA monitor controller

Four of these objectives were met completely during the Phase IV operations recorded to date. The final objective, the assessment of the impact of staggering on departure operations, has been met for all operations except those departures during the worst weather conditions under which CRDA will be used (i.e., a ceiling of 300 feet <u>and</u> visibility between 3/4 and 1 mile). The stringent weather conditions needed to complete the final assessment have not yet occurred. When St. Louis has been able to run those operations a separate appendix will be published to this report that details any additional findings or recommendations.

6.0 SUMMARY AND CONCLUSIONS

6.1 SUMMARY

During the period December 1990 through publication of this report, a four-phased operational evaluation of CRDA was conducted at Lambert-St. Louis International Airport. The intent of the evaluation was to determine the operational benefits of using CRDA at St. Louis, and to assess the operational suitability of the CRDA as a step toward possible national implementation of the aid at selected airports which have converging or intersecting runway configurations.

After controller training on the two CRDA modes of operation to be used at St. Louis -- tieing and staggering -- the CRDA was evaluated in an operational environment. Conclusions resulting from the evaluation are presented below. They are keyed to the three principal objectives described in section 3.0.

6.2 CONCLUSIONS

6.2.1 CRDA-Assisted Tieing Operations

6.2.1.1 Airport Operations Perspective

From the point of view of airport operations, the evaluation showed that the use of the CRDA does, in fact, provide the benefit of additional departure slots on runway 30R, while allowing triple runway arrivals to runways 24, 30R and 30L. Further, given that the weather conditions are such that use of the runway 30's/24 configuration is appropriate, and that the ceiling is at least 800 feet and the visibility at least 2 miles, St. Louis has identified no conditions which preclude the use of tieing; for example, no range of wind conditions has been identified which is considered so adverse as to preclude the use of tieing.

Guidance material on CRDA-assisted tieing, based on lessons learned during the St. Louis evaluation, was developed to assist in the national implementation of CRDA. Such material has been developed in the following areas:

- Preparing for the operational use of CRDA
- CRDA training
- Transitioning into the operational use of CRDA
- CRDA operational use

6.2.1.2 Controllers' Perspective

From the perspective of the tower and TRACON controllers, the evaluation showed that the controllers could use the CRDA to achieve accurate ties on a sustained basis. Further, the only CHI modifications identified during the evaluation were those which are already being provided in the national version of CRDA (i.e., in ARTS IIIA, Version A3.05). Several recommendations were made to St. Louis related to how to improve the use of CRDA-assisted tieing at St. Louis, but these recommendations were in the area of suggested procedural modifications, and were therefore unrelated to the CRDA software program itself.

Additional controller workload for the runway 24 final approach controller was reported, but this is to be expected if the benefits of increased arrival and departure throughput are to be realized by the facility.

6.2.2 CRDA-Assisted Staggering Operations using the DCIA Procedure

6.2.2.1 Airport Operations Perspective

The operational evaluation of the DCIA procedure, supported by the CRDA staggering application, has clearly shown that using CRDA-assisted staggering to support DCIAs provides an operational benefit to the facility by increasing the arrival throughput during IFR conditions. During pre-DCIA operations, the aircraft acceptance rate normally given to the Kansas City Center by the St. Louis TRACON was 36 aircraft per hour during IFR conditions. With DCIA and CRDA staggering, the rate given to the Center during IFR periods normally ranged between 42 and 48 aircraft per hour, depending on such factors as the visibility and anticipated departure demand. Analysis of CDR data further demonstrated that St. Louis did, in fact, routinely land more than 36 aircraft per hour using CRDA-assisted DCIA procedures during such periods when there was sufficient arrival demand.

At the time of issuance of this report, the Central Region had initiated the process of increasing the Engineered Performance Standards (EPS) for St. Louis from 36 to 48 aircraft per hour for the 24/30 R,L configuration when St. Louis is running DCIA and conditions exceed an 800 foot ceiling and 2 miles visitibility, and from 36 to 42 aircraft per hour down to CAT I weather minima. Although the EPS has not yet been officially changed, the ATC System Command Center (formerly Central Flow Control) will accept these rates if requested by St. Louis when DCIA and CRDA are operational. The EPS is the acceptance rate number used operationally in implementing national-level air traffic flow restrictions in poor weather conditions, or for other reasons affecting air traffic flow in large portions of the country.

In the area of airport operations, the St. Louis evaluation has also resulted in the conclusion that those facilities planning to use CRDA-assisted DCIA procedures to support DCIA should consider the use of a monitor position during stagger operations until sufficient experience is acquired with the aid that the facility feels either that the position is no longer needed, or that the position should only be staffed during specific operational conditions.

The last evaluation area related to airport operations was the impact of staggering operations on departures during combined arrival/departure rushes. It was concluded that as long as the tower controller had visual contact with the 30R arrival when it crossed the runway threshold, departure delays during CRDA stagger operations were not a significant problem at St. Louis. Although more data needs to be collected at this point, it appears from one experience during poor visibility that if there is substantial departure demand during CRDA-assisted stagger operations, there will be departure delays at St. Louis if visibility conditions are poor. The impact on departure operations is, however, dependent on site specifics (for example, distance from the tower to the threshold of the arrival runways); therefore, each site planning to use CRDA for staggering to support the DCIA procedure will need to evaluate

the impact on departure operations, if any, and to formulate the best operational strategy for dealing with this potential problem area.

As in the case of CRDA tieing, guidance material for the national implementation of CRDA stagger was developed in the areas of preparing for operational use, training, transitioning into operations, and operational use.

6.2.2.2 Controllers' Perspective

From the perspective of the TRACON and tower controllers, the evaluation showed that the controllers were able to consistently meet stagger separation requirements. Regarding the CRDA CHI for stagger operations, the general conclusion was that no modifications were required to the CRDA CHI interface for the St. Louis version of CRDA, and no modifications to the specified CRDA CHI were required for ARTS IIIA, version A3.05 (i.e., the national version of CRDA). Several recommendations were made related to suggested training or procedural modifications to either improve the use of CRDA during stagger operations at St. Louis or to aid in the national implementation of CRDA, but these recommendations were unrelated to the CRDA software program itself.

While CRDA-assisted staggering did not significantly increase workload for the TRACON controllers, tower controllers did notice a workload increase, as compared to their workload if single stream arrival operations were being conducted to runways 30R and 30L. However, this is to be expected if the benefit of an arrival throughput increase in IFR conditions is to be realized by the facility. It is expected that the difference in workload for tower controllers will diminish as more experience is gained with CRDA staggering operations by both the TRACON and tower controllers.

6.2.2.3 IFR Procedures Perspective

The last area of evaluation related to CRDA-assisted staggering was an assessment of the proposed IFR procedures to assure that an adequate margin of safety is provided when the aid is used to support DCIA procedures in IFR. The general conclusion from this evaluation is that the 2 nmi/5 nmi rule applied at St. Louis, with the several restrictions contained in the St. Louis waiver, does provide the required margin of safety for stagger operations at St. Louis.

7.0 RECOMMENDATIONS

Two major recommendations regarding the national implementation of CRDA can be derived from the operational evaluation of CRDA at St. Louis:

- Nothing was discovered about CRDA functionality or suitability for operational use which would preclude continuation of the national implementation of CRDA at other

airports which have converging or intersecting runways. It is therefore recommended that the planned national implementation of CRDA, using the functionality of ARTS IIIA, Version A3.05, be continued. Further, based upon formal and informal favorable comments received from various aviation user organizations during the St. Louis evaluation of CRDA, it is recommended that the national implementation of CRDA proceed as expeditiously as possible.

- As part of the activity of nationally implementing CRDA, it is recommended that the guidance material for national implementation contained in this report be made available to all sites that are considering the implementation of CRDA.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION 1

INTRODUCTION

1.1 PURPOSE

During the period December 1990 through the publication of this report, the operational demonstration of the Converging Runway Display Aid (CRDA), an automation aid for terminal air traffic controllers intended to enhance airport capacity, was evaluated at Lambert-St. Louis International Airport. The intent of the evaluation was to determine the operational benefits of using CRDA at St. Louis, and to assess the operational suitability of the CRDA as a step toward possible national implementation of the aid at selected airports which have converging or intersecting runway configurations.

The purpose of this report is to:

- Describe the evaluation method used
- Describe the results of the operational evaluation
- Document lessons learned during the evaluation at St. Louis and other CRDA related activities, to provide guidance for the implementation of the CRDA at other sites

This document is intended to be of use to the following organizations:

- Those Federal Aviation Administration Headquarters organizations which were responsible for deciding to implement CRDA nationally
- Those facilities that are considering introducing CRDA into their operations, during its national implementation.
- Those organizations which are generally cognizant of Air Traffic Control (ATC) capacity issues and planned system improvements for increasing capacity

1.2 BACKGROUND

During Visual Meteorological Conditions (VMC), air traffic controllers use visual procedures that allow operations on multiple runways simultaneously. However, during Instrument Meteorological Conditions (IMC) some runways cannot be used concurrently. The consequent erosion of airport capacity in IMC is the single most important cause of delays in the U.S. air traffic system [reference 1]. The conduct of staggered approaches to converging runways in IMC is one means of obtaining a needed increase in airport capacity by

permitting the safe use of multiple runways concurrently, even when weather conditions do not permit visual approaches.

Dependent Converging Instrument Approaches (DCIA) is a national program developed to increase airport capacity in IMC for those airports with converging or intersecting runways. The DCIA procedure permits controllers to provide minimum staggered separation on approaches to converging runways, while protecting against separation violations due to possible consecutive missed approaches. It is difficult, however, for controllers utilizing the DCIA to stagger aircraft precisely, especially on a sustained basis, without some type of visual controller aid.

The MITRE Corporation developed a concept for an automation aid -- known as the CRDA -- which could be used to assist air traffic controllers in maintaining the stagger distances established between aircraft at the runway thresholds using DCIA. In addition, the aid could be used for other operations, in either VMC or IMC, in which the distance relationship between aircraft on converging approaches is important to the safe and efficient utilization of the airspace and the airport. The basic function of the CRDA is to project position information (known as "ghost" targets) and associated alphanumeric data for aircraft on approach to one runway of the converging runway pair onto the final approach course of the other runway of the pair; thus enabling the controller to make better judgments regarding spatial relationships between aircraft approaching the converging runways. The reader who is interested in more detailed information on the problem of staggered approaches to converging runways and on the CRDA "ghosting" concept is referred to reference 1; appendix A contains a short summary of related information extracted from reference 1. A detailed description of the procedural implications of operating dependent instrument approaches to converging runways is presented in reference 2.

During Fiscal Year (FY) 1989, MITRE developed a laboratory simulation of the CRDA (also known as the "ghosting aid") for a St. Louis operational environment, and conducted experiments with controllers from the St. Louis Terminal Radar Approach Contro Facility to determine the utility of the aid and to identify desired design modifications. The experiments consisted of several phases, and the design of the aid evolved to reflect feedback from the St. Louis controllers. By the summer of 1989, the FAA, including St. Louis, considered the simulated CRDA version to be an effective aid for conducting staggered approaches for converging runways. Additionally, the St. Louis controllers identified an application of the aid -- known as "tieing" (see section 2.2) -- which applies during VMC conditions at St. Louis. The reader who is interested in further detail on the MITRE laboratory simulation is referred to reference 3. General results on the stagger and tieing experiments conducted at MITRE are reported in references 4 and 5 respectively.

In parallel with the laboratory simulations, a test National Airspace System (NAS) Change Proposal (NCP) [reference 6] was developed, coordinated, and approved. The NCP called for an operational demonstration of the aid at St. Louis to be evaluated under a DCIA test waiver permitting staggered approaches in IMC . The results of the laboratory simulations

were used to develop a functional specification of the aid for incorporation into Automated Radar Terminal System IIIA, Version 3.03 at St. Louis. Development and testing of the aid was conducted at the FAA Technical Center (FAATC). Prior to delivery of the aid to St. Louis, the software was tested to assure that functional stability was maintained in the conversion to the ARTS IIIA system. Testing at the FAATC also determined that the impact of the aid on computer utilization was negligible. In parallel with software development at the FAATC, extensive simulation testing was performed by MITRE to assure that adequate spatial and time separations would be provided for a variety of situations in the unlikely case that consecutive missed approaches were to be executed.

After delivery of CRDA to St. Louis in ARTS IIIA, Version 3.03, and completion of site acceptance testing, the operational evaluation of the CRDA, as reported in this document, commenced. In parallel with the initial operational evaluation, the CRDA software patch was converted to Version 3.04 of the ARTS IIIA System, and the remainder of the evaluation at St. Louis was performed using the 3.04 Version.

1.3 SCOPE

A detailed Operational Evaluation Plan (OEP) was written and coordinated within the FAA, including St. Louis, prior to the start of the operational evaluation [reference 7]. That plan describes the goals of the evaluation, the phases of the evaluation, the overall approach to the evaluation; and specific procedures, data collection requirements and evaluation techniques. While the plan served as the general roadmap for the evaluation, as the evaluation proceeded it was necessary to make several mid-course corrections to the evaluation approach. These adjustments to the originally-planned evaluation approach are described, along with the rationale for each, and a description of the manner in which the original objectives were achieved.

1.4 DOCUMENT ORGANIZATION

The remainder of this document is organized as follows. Section 2 describes the operational uses of the CRDA at St. Louis in order to establish the context for the operational evaluation. The objectives of the evaluation are presented in section 3. Section 4 describes the approach used during the evaluation, both the technical approach and the project management approach. The results of the operational evaluation are presented in section 5 for each phase of the evaluation. A summary of the evaluation is presented in section 6, followed by conclusions and recommendations in section 7. Supporting information is presented in appendices A through G, and the contents of each appendix is described in the main body of the report. Two appendices which are particularly noteworthy are appendix F, which contains letters summarizing initial aviation user reaction to the use of CRDA stagger operations in Instrument Flight Rules conditions; and appendix G, which contains a summary

of guidance material for use by other sites that intend to use CRDA with the 3.05 Version of ARTS IIIA.

SECTION 2

GENERAL USES OF THE CRDA AT ST. LOUIS

To best understand the objectives and results of the evaluation of the use of CRDA in an operational environment at St. Louis, it is important to have an understanding of the ways in which CRDA was operationally used at St. Louis. The CRDA was used in two modes of operation at Lambert-St. Louis International Airport. In the first mode -- known as staggering -- the aid was used in IMC in order to improve arrival throughput; in the second mode -- known as tieing -- the aid was used in VMC to improve both arrival and departure throughput. The principal area of interest during the operational evaluation was the stagger mode of operation, since use of this mode in IMC is expected to provide the greatest capacity benefits at selected airports with converging or intersecting runway operations. Figure 2-1 depicts the layout of Lambert-St. Louis International Airport, and the following sections describe the two modes of operation.

2.1 STAGGER OPERATION

Prior to the introduction of the DCIA waiver and implementation of CRDA, when ceiling and/or visibility conditions precluded the simultaneous use of the parallel runways 30R and 30L, St. Louis would use staggered approaches to converging runways 30R and 24 until the ceiling and visibility dropped to values such that the local controller could not acquire aircraft visually before losing 3 nautical miles (nmi) lateral separation between aircraft on the converging secondary stream. In practice, this meant that the local controller had to visually acquire the aircraft for runway 24 by the time it was about 2 nmi from the threshold, and this in turn is usually achievable down to a ceiling of about 800 feet. When meteorological conditions degraded below this point, converging approaches were discontinued and a single arrival stream was used to runways 30R/30L. When a single arrival stream must be used, the usual acceptance rate for the airport is 36 aircraft per hour.

The test waiver for St. Louis [reference 8, included as appendix C] permitted dependent converging instrument approaches to runways 30R and 24 during IFR conditions down to Category (CAT) I minima as long as a minimum stagger of 2 nmi was provided between successive arrivals on the converging approach paths, or a 5 nmi

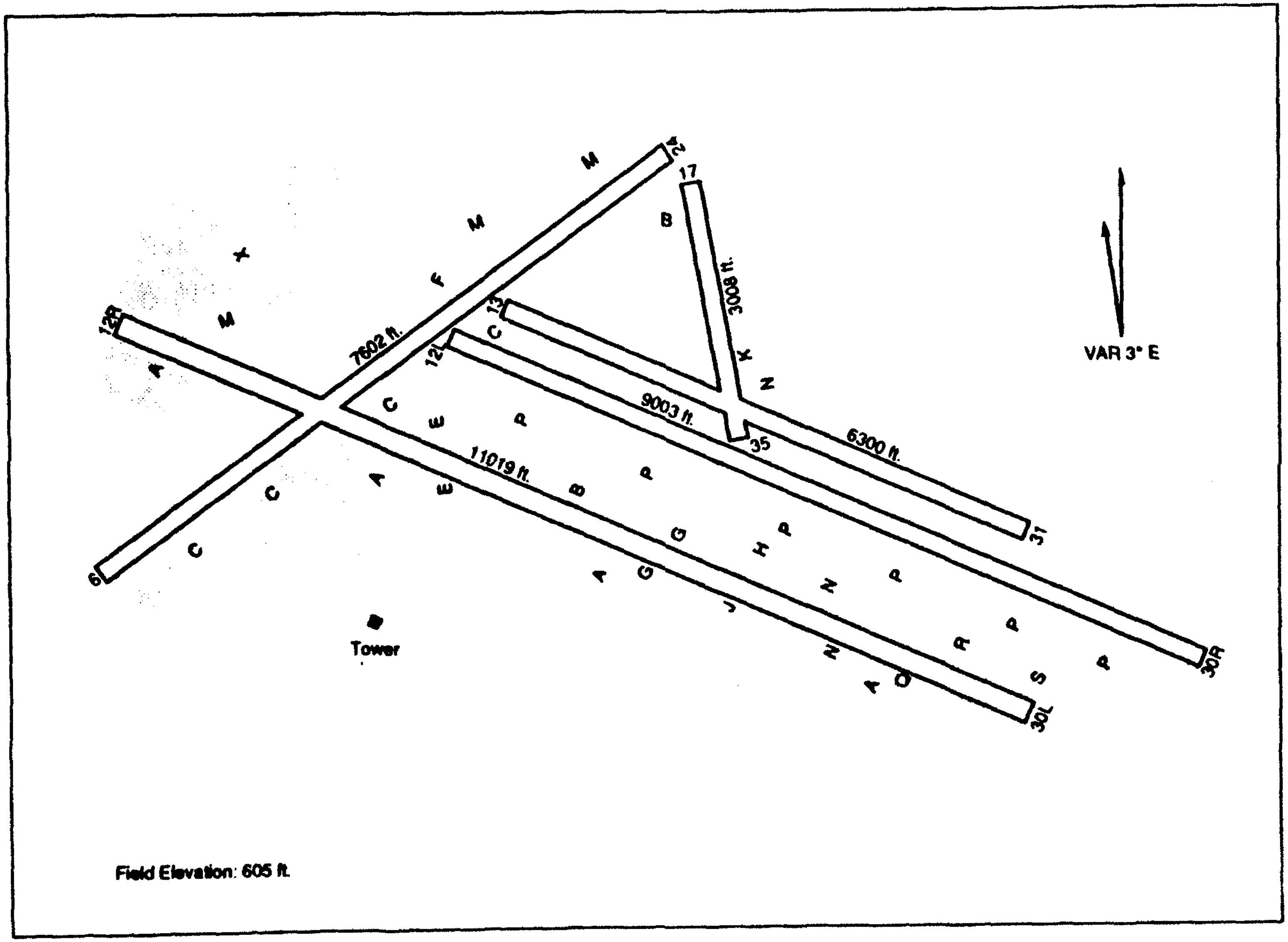

Figure 2-1. Layout of Lambert-St. Louis International Airport

stagger if the leading aircraft was a heavy.[2] In this mode of operation, departures would use runway 30L.[3]

When CRDA is used to support DCIA in the stagger mode, data on aircraft approaching 30R is projected (i.e.,"ghosted") and displayed at the control position of the runway 24 final approach controller, and data on runway 24 arrivals is ghosted to the 30R final approach control position. This data consists of a ghost position symbol, an optional line of data containing a coast indicator (if applicable), a heavy jet indicator (if applicable) and/or ground speed; a leader line is also displayed if the optional line of data is displayed. The control positions for the 30R and 24 final approach controllers were physically adjacent during stagger operations so as to facilitate verbal coordination between the two controllers. The controllers used the data provided by the aid, and coordinated between themselves, to separate the approaching aircraft in order to achieve the required stagger distances.[4] The expectation was that use of this dependent stagger operation would permit St. Louis to land more than 36 aircraft an hour in IMC conditions down to CAT I.

2.2 TIEING OPERATION

In Visual Flight Rule (VFR) conditions, and when landing to the west and south, St. Louis can achieve its maximum arrival throughput when runways 24, 30R and 30L are all used simultaneously for arrivals. Before the introduction of CRDA, however, St. Louis often had to discontinue landings on runway 24 as traffic demand increased due to a dependency between runway 24 arrivals and runway 30R departures. Note from figure 2-1 that since the flight path for 30R departures intersects the flight path of the 24 arrivals, arrival and departure operations on these two runways need to be coordinated.

The operational solution applied to this problem is for the controllers to attempt to "tie" arrivals on 30R and 24; that is, to have the 30R arrival reach the runway threshold at about

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2 A stagger distance of R nmi between a pair of aircraft approaching converging runways means that when the lead aircraft is at its runway threshold, the trailing aircraft should have R more miles to the intersection of the converging runways than does the lead aircraft.

3 There were several other specific restrictions in the test waiver; they are addressed in Section 5.3.4.1.

4 Preliminary analysis performed by MITRE had shown that if the stagger distances are provided, then even in the unusual case of consecutive missed approaches to the converging runways, adequate spatial separation and time separation (for wake vortex avoidance) at the runway intersection was expected. This preliminary analysis was later extended in the form of extensive simulation testing to validate the general conclusion.

the same time that the runway 24 arrival reaches the runway 24 threshold. If this can be accomplished, then while the 30R arrival is taxiing off the runway, the 24 arrival will have taxied off the runway or will have rolled past the 24/30R intersection point (i.e., the point at which 24 and 30R would intersect if 30R were extended). If the next departure on 30R is instructed by the local controller to "position and hold" on runway 30R as soon as the 30R arrival touches down, and is released for takeoff as soon as the 30R arrival clears the runway, then there is a natural gap in the 24 arrival stream (due to standard longitudinal separation standards) which permits the 30R departure to takeoff and clear the intersection with adequate separation. Tieing arrivals reduces "dead time" and maximizes the number of 30R departures which can be achieved during triple runway arrival operations. The problem in pre-CRDA operations was that the controllers were not able to achieve satisfactory ties on a sustained basis because it was difficult to maintain a mental picture of the spatial and timing relationships between the aircraft on the converging streams; and attempting to do so during heavy traffic conditions had an adverse impact on the controllers' ability to perform other control tasks. The net effect was that arrival operations to runway 24 often needed to be discontinued in order to accommodate the release of departures.

The CRDA provides visual assistance to the controllers in performing the tie operation. In this mode of operation, aircraft approaching runway 30R are ghosted to the runway 24 final approach control position. The data presented to the controller in the ghost data block is the same as that provided during staggering operations. The runway 24 approach controller uses the ghost data by attempting to superimpose the position of an actual runway 24 arrival onto, or slightly behind, the ghost of the corresponding 30R arrival. The controller accomplishes this by issuing speed and vector control commands to aircraft approaching runway 24 in order to cause the tieing of the 24 and 30R arrivals. The local controller in the tower makes the final decision as to whether the tie was good enough to permit a departure on 30R.

SECTION 3

OBJECTIVES OF THE EVALUATION OF CRDA OPERATIONS

The principal objectives of the evaluation of the St. Louis operational use of DCIA and CRDA can be stated in terms of a series of high-level questions from the following perspectives:

-- From the viewpoint of airport operations, (a) does the aid provide an operational benefit to the facility?; (b) how can the aid best be used to facilitate St. Louis operations?; and (c) what can be learned at St. Louis to support the implementation of the aid at other facilities during national implementation?

-- From the viewpoint of the controller (TRACON and tower controllers), does the aid need to be modified prior to national implementation to improve its utility in an operational environment? If so, how?

-- From the viewpoint of IFR procedures to be used with the aid, do the proposed IFR procedures assure that an adequate margin of safety is provided when the aid is used to conduct staggered, converging approaches in IFR?

Each of these high-level questions was broken down into more specific questions to guide and focus the operational evaluation at St. Louis.

3.1 AIRPORT OPERATIONS PERSPECTIVE

From the viewpoint of airport operations, the evaluation was focused on answering questions such as the following:

-- What is the magnitude of the operational advantage to the facility, and under what conditions is the benefit achieved?

-- What are the general conditions when the aid should and should not be used?

-- How can the aid best be phased into operational use?

-- What is the optimum stagger distance to be used during various operational conditions?

-- What is the best operational strategy for getting departures out during overlapping arrival/departure rushes when stagger operations are in effect?

-- Is a final monitor controller needed to provide added assurance that required separation is provided during IMC stagger operations?

Although the evaluation was oriented toward answering each question specifically for St. Louis, an important related objective was to support the national implementation of the aid by determining areas where lessons learned about the use of the aid at St. Louis may be applicable at other sites.

3.2 CONTROLLER PERSPECTIVE

Operational evaluation from the perspective of the air traffic controller was oriented toward answering questions such as the following:

-- Is the appropriate data displayed to the controller?

-- Is the data displayed in a timely manner and is it removed from the display in a timely manner?

-- Is the display format satisfactory? Is there clutter due to ghosting, and is it a problem?

-- Are the optional display features adequate?

-- Are the features for enabling and disabling the aid adequate?

-- Can the aid be used to accurately stagger aircraft for a range of expected wind conditions, traffic patterns, etc.?

-- Can the aid be used to accurately tie aircraft for a range of expected wind conditions, traffic patterns, etc.?

-- Are the techniques for inter-controller coordination adequate?

-- What are the effects of using the aid on other controller tasks?

3.3 IFR PROCEDURES PERSPECTIVE

As noted earlier, MITRE had performed preliminary analyses to show analytically that if a stagger distance of 2 nmi (5 nmi behind a heavy aircraft) is provided at the runway threshold, then even in the unusual case of consecutive missed approaches to the converging runways, adequate spatial separation and time separation (for wake vortex avoidance) at the runway intersection would be provided at St. Louis. Not only are consecutive missed approaches

very unlikely occurrences, but this worst case analysis further assumed that there would be a simultaneous radio failure, meaning that the controller would not intervene and that both aircraft would make straight-out missed approaches through the intersection.

As further assurance that the proposed IFR procedures for use with the aid provide the required margin of safety, extensive simulation testing was conducted by MITRE prior to the use of staggered approaches with the aid in IFR conditions at St. Louis. This testing included numerous cases of consecutive missed approaches to assure that the expected spatial and time separations are achieved for the range of missed approach types which might occur at St. Louis. Further details of this analysis are provided in section 5.3.4. This analysis was supplemented by a flight demonstration involving live aircraft which flew consecutive missed approaches at St. Louis. The results of the live flight demonstration are also presented in section 5.3.4.

SECTION 4

APPROACH TO THE OPERATIONAL EVALUATION

This section describes the technical and operational approach to the evaluation of CRDA at St. Louis, and the mechanisms used for project management during the evaluation.

4.1 TECHNICAL AND OPERATIONAL APPROACH

The evaluation of the CRDA at St. Louis was performed in an operational demonstration environment. That is, after suitable training, the aid was demonstrated in air traffic operations by the TRACON and tower controllers, and the evaluation was conducted in that context. The evaluation of the operational demonstration of CRDA at St. Louis, which is the subject of this report, is referred to hereafter as the CRDA "operational evaluation".

The overall St. Louis plan for the use and evaluation of the aid [reference 7] called for all TRACON and tower controllers to be trained in the use of the aid, with the entire controller complement progressing through the various phases of the evaluation as a single "class" (see below for a description of the phases). The goal was for all controllers to be brought to an equivalent level of training and operational proficiency with the aid before advancing together to the next phase of the operational evaluation. This approach was chosen to simplify training and the evaluation process, and to facilitate the gradual, orderly transitioning of the aid into full-scale operations at St. Louis.

The operational evaluation was conducted in two ways. The formal portion of the evaluation consisted of the minimum essential steps required to fully and formally evaluate the use of the aid at St. Louis. The formal evaluation was the principal basis of this report on the results of the St. Louis operational evaluation. The formal evaluation process consisted of: (1) the use of questionnaires to elicit controller views on the Computer/Human Interface (CHI); (2) the conduct of evaluation periods during which observers were positioned at key locations and completed evaluation logs, noting significant events; (3) the collection of quantitative ARTS data on magnetic tape for purposes of obtaining objective evaluation data such as arrival throughput; (4) the conduct of structured controller group debriefings; and (5) the conduct of periodic Project Management Reviews (PMRs) and Operational Readiness Reviews (ORRs) (described in section 4.2).

The formal evaluation was augmented by an informal, day-to-day evaluation. The informal evaluation consisted of both visual observations by non-controller personnel and manual logs maintained in both the tower and the TRACON. The informal evaluation was a principal input in determining the required extent of the formal evaluation. Findings from the informal evaluation were primarily reported and discussed during weekly project telephone conferences. Those conferences were added to the original evaluation plan by the project

team as a result of an unforeseen schedule slip following Phase II in an attempt to prevent future schedule problems.

The operational evaluation proceeded in several phases, as defined in the test National Change Proposal (NCP) for the aid [reference 6], and as illustrated in figure 4-1[5]. As mentioned earlier, the entire complement of TRACON and tower controllers moved from one phase to the next as a single group. The decision to proceed to the next phase was made at ORR meetings (see section 4.2), and included consideration of factors such as (1) whether all controllers had been sufficiently trained and had achieved a suitable level of proficiency in operational use of the aid during the previous phase, (2) whether related operational procedures had been validated or refined as necessary, and (3) whether the formal evaluation planned for the previous phase had been completed satisfactorily.

Phase I of the operational evaluation involved training controllers and supervisors in the use of the aid, for both tieing and stagger operations. This is described in more detail in section 5.1. Such training consisted of classroom training and hands-on training with the Enhanced Target Generator (ETG).

After the completion of training, Phase II commenced with the aid being used in actual operations to perform tieing during VFR conditions. This approach was expected to provide St. Louis with an early benefit from the use of the aid. Also, since tieing is performed in VFR conditions and such conditions predominate at St. Louis, it was expected that there would be ample opportunity for the full complement of controllers to gain early operational experience with this application of the aid.

Phase III of the operational evaluation consisted of using the aid to perform stagger operations in VFR conditions. Although the stagger aid would normally be used in IFR conditions, there were several reasons for this phase of the evaluation, including the following:

- Sustained periods of IFR conditions are infrequent at St. Louis, so opportunities for controllers to use the aid in IFR and to become proficient in its use would be limited. The approach of performing stagger operations in VFR conditions was therefore expected to facilitate the process of giving controllers operational experience with this application of the aid.

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5 Section 1.7 of the test NCP describes a three-phased evaluation at St. Louis, with the second phase consisting of evaluation of both the tieing and staggering operations in VFR weather conditions. In the operational evaluation plan for St. Louis [reference 7], this second NCP phase was broken into two phases to better distinguish between the tieing and stagger evaluation portions of that phase. NCP Phase 3, evaluation of stagger operations in IFR conditions, was then designated as Phase IV in the St. Louis evaluation. See figure 4-1.

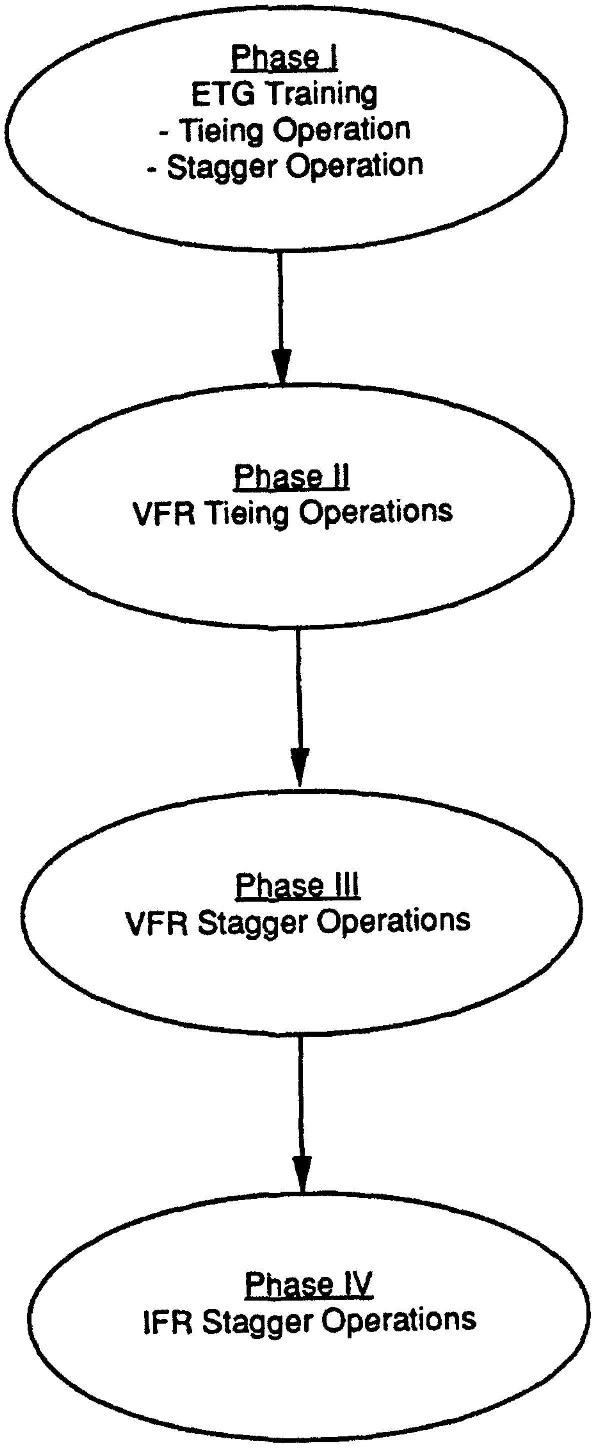

Figure 4-1. Phases of St. Louis Operational Evaluation of the CRDA

-- Stagger operations in VFR conditions provide a more tolerant environment (than IFR) for controllers to gain operational experience with this version of the aid. For example, if a TRACON controller were to provide too little stagger, the local controller could take an early action to avoid a loss of separation since he/she would be able to visually acquire the aircraft before a loss of radar separation occurs.

-- The IFR procedures for use of the aid for stagger operations could be evaluated in VFR conditions, and modifications made, if necessary, before proceeding to stagger operations in IFR conditions.

The last formal phase of the operational evaluation at St. Louis -- Phase IV -- consisted of using the aid to support staggering operations in IFR conditions. During this phase, the IFR procedures developed under the test waiver for St. Louis were used, and a monitor controller was stationed in the tower to ensure that at least minimum separation was provided between aircraft executing converging approaches. As mentioned in section 2, use of the aid in this mode of operation was expected to result in arrival throughput gains at St. Louis.

4.2 PROJECT MANAGEMENT APPROACH

Several project management mechanisms were used to maintain management control of the operational evaluation of CRDA at St. Louis. Such mechanisms allowed FAA CRDA program managers, other FAA Headquarters organizations, Central Region representatives, facility management at St. Louis, and MITRE evaluation and management personnel to have up-to-date information on the progress of the evaluation. The project management mechanisms also provided forums wherein problems associated with the evaluation could be discussed and resolved. The following project management mechanisms were used during the evaluation of CRDA at St. Louis. They are listed in decreasing order of formality:

-- ORR: An ORR was held at the completion of each formal phase of the evaluation. This was a formal decision-making meeting, the main purpose of which was to make a "go/ no go" decision as to whether the evaluation should be authorized to proceed to the next phase. The format used for the CRDA ORRs was (1) presentations summarizing the results of the just-completed phase of the evaluation, (2) discussion of the results, and a decision as to whether to proceed to the next phase, and (3) presuming a "go" decision, a presentation which provided a preview of the next phase of the evaluation, describing the approach, evaluation activities to be accomplished, specific roles and responsibilities, and an initial schedule. These meetings were usually attended by FAA CRDA program managers, representatives from other interested FAA Headquarters organizations, FAATC representatives, Central Region representatives, management and other representatives from St. Louis, and MITRE personnel.

- PMR: These were less formal, working-level meetings which were held between ORRs to review the overall status of the evaluation. The purpose of the project management reviews was to:

  - Review overall progress and problems related to the operational evaluation, and assign action items to resolve outstanding problems

  - Discuss any significant procedural modifications or design modifications to the CRDA which have been proposed; decide whether to accept the proposal and implement the modification; determine whether the modification needs to be formally re-evaluated after its implementation and use

  - Review planned operational evaluation activities to be conducted prior to the next scheduled project management review, and specific goals of the evaluation

  - Identify if any significant modifications to the operational evaluation approach as defined in the evaluation plan were required

  - Identify any additional areas of operational evaluation which may be required beyond those addressed in the evaluation plan

These meetings were usually attended by FAA CRDA program managers, FAATC project personnel, management and evaluation staff from St. Louis, and MITRE; and sometimes representatives from other FAA Headquarters organizations and the Central Region.

- Periodic Project Telephone Conferences (TELECONs): These were informal, periodic TELECONs to generally discuss progress and problems associated with the evaluation, and to coordinate among the principal organizations involved with the field evaluation. Participants were designated by the CRDA program office, and generally included the same organizations which participated in the PMRs. On the CRDA project, such TELECONs were started at the end of March 1991, and were held weekly throughout the remainder of the CRDA evaluation at St. Louis. The TELECONS were added to the original evaluation plan in an attempt to provide improved control over the project schedule.

At the conclusion of Phase IV, a CRDA Operational Evaluation Review will be conducted to review the overall evaluation of CRDA at St. Louis (i.e., Phases I through IV) and to determine whether the formal CRDA evaluation activities should be concluded at St. Louis.

SECTION 5

RESULTS OF THE EVALUATION

This section describes how each of the four phases of the operational evaluation was conducted within the operation environment provided at St. Louis; it also summarizes modifications made to the original evaluation plan as the need for such revisions was identified, and it presents the results of each phase of the evaluation.

5.1 PHASE I: CRDA TRAINING

5.1.1 General

Proper training was considered critical to successful implementation of the CRDA at St. Louis. Although the controllers at St. Louis had previously used manual tieing and stagger techniques with arrivals to the converging runways, the display of a ghost target was new to them. Potential controller concerns with CRDA as an automation aid needed to be addressed. The controllers had to develop a high level of confidence in the accuracy of the computer-generated ghost target, before it could be used in actual operations. Further, the training phase needed to address controller concerns regarding whether there would be sufficient separation at the intersection in the case of consecutive missed approaches during stagger operations. The CRDA training program conducted at St. Louis was implemented by the training staff at St. Louis in coordination with representatives of the St. Louis Plans and Procedures staff. MITRE personnel supported the evaluation of that program, as described below.

CRDA training consisted of technical briefings for all controllers and supervisors, as well as hands-on ETG experience for the TRACON controllers and supervisors, and ETG demonstrations for the tower personnel. This was accomplished by having each controller first attend a detailed briefing on tieing and staggering, followed by a period of questions and answers intended to resolve any controller uncertainties about the aid. Following the briefing, each TRACON controller received experience in the ETG Lab handling simulated aircraft while running both tieing and staggering operations.

One hour classroom briefings were held for the TRACON controllers and supervisors from 11 December 1990 through 3 January 1991. Tower controllers and supervisors were briefed from 12 December to 19 December 1990.

On 7 January, TRACON supervisors and training personnel were provided hands-on CRDA experience in the ETG laboratory. ETG laboratory training was then conducted for the TRACON controller staff from 8 January until 14 January. Training sessions lasted approximately 4 hours, with two controllers being trained per session. The controllers

alternated handling simulated traffic arriving at runways 30R and 24. They were first trained on the tieing application; and once they were comfortable with tieing, they were then trained on the stagger application.

During the ETG simulations, each controller was paired one-on-one with a CRDA trainer, who also acted as a "pilot-in-the-loop" for the aircraft being controlled. For example, if a controller instructed an aircraft to turn right 20 degrees, the trainer, acting as pilot, would make the necessary entry to have the aircraft make the designated maneuver. In addition to explaining the CRDA concept, the trainers also helped the controller through the scenarios, answering questions or providing suggestions as to a recommended controller technique. As an example, a trainer might suggest that an aircraft not be brought straight in, but rather turned out and brought back in to make it easier for the controller to achieve the desired separation.

Initially, hands-on ETG training was not considered necessary or appropriate for tower controllers. However, following training of the TRACON controllers, the tower controllers had an opportunity to observe the CRDA simulations being run. On 16 January 1991, the tieing and stagger functions were demonstrated in the ETG laboratory for several groups of tower controllers and supervisors. Tower controller responsibilities and areas of concern were discussed during these training sessions. These group training sessions lasted approximately one half hour each.

As a final training aid, a videotape was prepared at St. Louis to provide refresher training on an "as needed" basis for the controllers. The videotape included much of the same information provided in the initial briefings, updated to reflect lessons learned and changes made as a result of the ETG training sessions. The videotape also showed controllers running the CRDA simulation in the ETG room; this was intended to further familiarize the controllers with the CRDA symbology that would be presented on the Plan View Displays.

5.1.2 Evaluation Performed and Results

5.1.2.1 Evaluation of Training Program

The CRDA training program conducted at St. Louis was evaluated both in terms of the adequacy of the training and the appropriateness of the training procedures themselves. The evaluation was conducted by the training staff at St. Louis, in conjunction with representatives of the St. Louis Plans and Procedures Staff, and was supported by MITRE. The intent was to use the training methodology employed by St. Louis, along with lessons learned during training, to develop training guidance material which would be relevant for the national implementation of CRDA. The resulting training-related guidance material is presented in appendix G.

Evaluation of the training program itself resulted in the following findings:

- The CRDA training program was considered to have effectively prepared all St. Louis TRACON control personnel who would participate in the CRDA operational demonstration. This included:
  - All TRACON Full Performance Level controllers and supervisors
  - All Area Managers
  - All developmental controllers who had been previously trained at the Runway 24 Final Approach position
- Although it was not evident during the training phase, it became apparent in subsequent phases of the evaluation that the tower controllers and supervisors should have been trained more extensively and, in general, should have been more involved in the planning aspects of the evaluation. (Additional CRDA training for tower personnel was later provided at St. Louis.)
- Prior to the start of TRACON and tower controller training, a cadre training technique was used to (1) familiarize the St. Louis training staff with the CRDA, (2) train several ATC specialists so that they could augment and work with the training staff in training the controllers, and (3) familiarize St. Louis Plans and Procedures staff and management, and other facility management representatives, with the CRDA. This cadre training was considered by St. Louis to be an essential step prior to the start of controller training. Specifically, cadre training provided familiarity with the ETG simulation, and valuable experience which was later employed in training the remaining controllers. It also helped the training staff to become familiarized with the simulation scenarios, and to find the best ways to resolve certain scenario situations. However, additional time to put together a comprehensive training program and more ETG practice time for the trainers would have been beneficial. Therefore, for future implementations it is recommended that the training staff be provided sufficient time to familiarize themselves and their cadre training assistants with the CRDA training simulation, and to tailor the training program to their site.
- Training of the controller supervisors and TMCs provided them with both hands-on understanding of CRDA and appreciation of the benefits offered by the program. This permitted the supervisors and TMCs to play an instrumental role in the acceptance of CRDA by the controllers. It also pointed up the important role of the TMC and TRACON supervisor, along with the feeder controller, in establishing the traffic streams during stagger operations.

- Training of all tower personnel, including the LC-3 (i.e., monitor) position, both through classroom training and ETG simulation, should be required in order to prepare the tower controllers for what they can expect during CRDA operations. St. Louis allocated approximately thirty minutes of ETG training per tower controller crew, in addition to prior classroom training. For implementation at other sites, more extensive training of tower control personnel is recommended, and such training should be provided to each tower controller on an individual basis.

- Prior to running CRDA operationally, controllers were trained on both the tieing and staggering functions; however the initial operational evaluation phase was limited to the tieing application. The techniques for setting up traffic streams differ between the two functions (for example, the feeder position plays a much more critical role in the implementation of stagger). Since it was several months between the start of tieing operations and the start of stagger operations with CRDA, it was necessary to provide refresher training to the controllers on staggering operations with CRDA. This has led to the recommendation, contained in appendix G (guidance material for national implementation), that if CRDA is to be used for several applications at a site, then training for each application should be conducted for the controllers just prior to the initial operational use of that application.

- It was found to be very important for training personnel to continually stress the need for coordination between the controllers of the converging runways throughout the ETG session. For example, the St. Louis controllers need to remember to enter the landing runway into the scratchpad area in a timely manner in order to generate the ghost targets on the converging runway.

- It may be necessary to use several training teams in order to maximize the availability of the ETG training facility. If there is more than one training team, it is essential that the training personnel from the different training teams, even if they are working different shifts, coordinate to assure consistency of training across the teams. For example, during stagger training at St. Louis, one team determined that it was beneficial to assign one controller a feeder role in order to facilitate the workload of the controller downstream. This technique was then incorporated into the training program by the other training team.

- Based on St. Louis' experience, it was found that it is best not to go into great depth during the classroom training, but rather to advise the controllers that most of their questions will be answered better during a "hands-on" ETG demonstration immediately following the briefing. The classroom briefer should explain briefly what CRDA is, what CRDA is to accomplish, and any other information he/she feels may be beneficial, but rely on an ETG demonstration of the CRDA as the principal vehicle for handling questions which the controllers may have.

- St. Louis personnel agreed that the four hours of ETG training per controller, the time allotted at St. Louis, was appropriate for CRDA training prior to the start of Phase II. However, the reader should bear in mind that this length of time was used to train both the tieing and stagger applications of the aid. One might estimate, then, that approximately two hours of ETG training may be necessary to train controllers in each application of the aid to be used at a site (which may include applications other than the tieing and staggering applications used at St. Louis). However, this rule of thumb may need to be modified based on the complexity of the application being trained and other factors such as whether the training philosophy calls for training with only "benign" scenarios, as opposed to more extensive training with both "benign" scenarios and "stress" scenarios. (See appendix G for further detail regarding scenario use during training.)

- For developmental and full performance controllers hired in the future, and any existing developmental controllers not yet trained in the use of CRDA, St. Louis plans to include CRDA training in the last portion of the low altitude phase of the St. Louis training program, rather than to have a special CRDA training program.

Training-related guidance material for the national implementation of CRDA, based on St. Louis' training approach and resulting lessons learned, is presented in appendix G.

5.1.2.2 Preliminary Evaluation of CRDA CHI

A preliminary evaluation of the CRDA CHI was also performed during ETG training. Air Traffic Service headquarters representatives, in conjunction with the St. Louis Test Manager, used the ETG training phase to obtain initial controller feedback regarding the operational suitability of the display of CRDA data and associated data entry capabilities.

Based on the controller comments received during the training phase, it was not deemed necessary to make any changes to the CRDA application software prior to the commencement of the operational evaluation at St. Louis. However, St. Louis identified several shortcomings of the CRDA software version which was delivered to St. Louis, and recommended that they be addressed in the design of ARTS IIIA, Version 3.05, the first version of ARTS which would include CRDA for national implementation. The software shortcomings which St. Louis felt should be corrected for the national implementation of CRDA were as follows:

- The site needs to be able to run the CRDA training scenarios concurrently with the operational version of the program. The inability to do this with the St. Louis A3.04 version of CRDA caused difficulties at St. Louis, where they were unable to support training while still providing operational readiness.

- Once a ghost target was dropped, the only way to reestablish that target was to enter the F7 N ALL message. The controllers felt that this was not an acceptable nor

efficient way to reestablish the target. It was suggested that F7 N, SLEW to the desired target, be accepted. The controllers did not want to be required to bring back all dropped targets just to see a single desired dropped target.

- The tower controllers felt that they should not be required to enter "Quick Look" functions during CRDA operations in order to cause display of ghost targets in the tower. They must see the ghosts for separation purposes, and therefore suggested that the ghosts be displayed in the tower automatically whenever the CRDA function is enabled.

- All positions need to have individual control of the ghost data blocks. Several problem areas were identified during Phase I, including:

  -- Once a position in the TRACON dropped a ghost target, it was also dropped from the tower display. This was not acceptable since the tower shared responsibility for separation during stagger operations.

  -- Tower personnel may need to move the ghost leader line to better suit their operational needs. However, that capability was not provided.

  -- Tower personnel should have the ability of deleting selected ghost targets during the quick look function without affecting any other controller's display.

- The CRDA "Quick Look" function should be simplified. A suggested solution is an on/off entry of the position symbol of the position to be "Quick Looked" followed by a G (as in Ghost).

All these deficiencies have been addressed in the design of the 3.05 version of ARTS IIIA in the sense that the functional capability desired by St. Louis has been provided; however, the design approach to providing the functional capability has in some cases been different from that recommended by St. Louis.

In evaluating the CHI during training, one area was identified for modification which is airport specific. The consensus of controllers and trainers was that the triangular ghosting region used for tieing at St. Louis was too narrow. The controllers wanted to see the ghosts appear on the screen sooner than provided using these narrow ghosting region definitions. Specifically, the later the 24 controller saw the 30R ghost targets, the less time the controller had to respond to the situation and the more difficult it became to handle/vector short turns into the arrival stream. However, it was decided to evaluate this further during actual tieing operations, when the controllers would have a better understanding of exactly what size would be optimal for the ghosting region. Expanding the ghosting region too far would result in unacceptable clutter on the display. During Phase II (i.e., actual tieing operations with CRDA), the optimum ghosting region size was better determined and was correspondingly revised at that time.

5.1.3 Results of the ORR

An ORR was held at St. Louis on 25 January 1991. The main purpose of the ORR was to review the progress of Phase I of the CRDA evaluation, to preview the upcoming Phase II evaluation (i.e., live tieing operations using CRDA), and to decide whether or not to authorize the start of Phase II. Attendees included representatives from St. Louis Tower, the CRDA Program Office (ARD-40), Air Traffic Plans and Requirements (ATR)-210, FAATC ACD-340, the System Capacity and Requirements Office (ASC)-201, and MITRE. The outcome of the ORR was that St. Louis was authorized to proceed with Phase II of the CRDA evaluation, to commence on 29 January 1991 or as soon thereafter as permitted by weather conditions.

During the ORR, St. Louis personnel reviewed the training approach and results, as described in section 5.1.2, and several suggestions were made regarding CRDA training for national implementation. The guidance material for CRDA training at other sites, presented in appendix G, includes the training recommendations made by St. Louis. St. Louis also reviewed those CHI software limitations of the CRDA which were identified during the training phase (see section 5.1.2). Despite these shortcomings of the St. Louis version of CRDA, St. Louis indicated that none of them would preclude the operational use and evaluation of the CRDA. St. Louis facility managers expressed a desire to move on to Phase II, and indicated that procedural changes would be used to bypass the software limitations so that the evaluation could proceed. St. Louis also concluded that the ghosting region for the tieing application should be modified, but decided to wait until experience was gained with actual operations in Phase II before determining the desired change and implementing it via a software modification.

St. Louis also described one operational lesson learned during training which would be carried forward into stagger operations in Phase III. A decision was made to designate runway 30R as the primary runway for all heavy aircraft so as to lessen the coordination, and simplify the handling, of such aircraft. With this approach, the controller responsible for the heavy aircraft would follow the heavy with another aircraft on the same runway. The controller working the heavy would establish a final with the desired spacing, and the controller working the converging runway then only had to space his/her aircraft between all gaps not preceded by a heavy aircraft. This operational technique also has the advantage of avoiding wake turbulence at the projected runway intersection in the unlikely case of consecutive missed approaches.

5.2 PHASE II: TIEING OPERATIONS IN VFR

5.2.1 General

The principal objectives of Phase II of the CRDA operational evaluation were to determine (1) the suitability of the CHI in conducting tieing operations, (2) the ability of the controllers to achieve effective ties with the aid, and (3) the impact of effective tieing on St. Louis operations. Controller questionnaires, structured controller group debriefings, and project management reviews were used to determine how well these objectives were being met throughout this phase.

Phase II of the CRDA operational evaluation began on 29 January 1991. At the start of Phase II, St. Louis conducted tieing operations, using the CRDA ghosting aid, during VFR weather conditions with a ceiling of 1500 feet and visibility of 4 miles or greater. On 4 February, St. Louis reduced the weather minima for tieing operations to a 1000 feet ceiling and 3 miles visibility or better. The final weather step-down took place on 12 February, when St. Louis began to run CRDA tieing down to a ceiling of 800 feet and visibility of 2 miles or better. Throughout Phase II, it was required that the local controller be able to provide visual separation prior to losing standard radar separation. (Note that although, for convenience, this phase is referred to as "VFR tieing", the phase actually included operations in "high IFR" -- i.e., below 1000 feet ceiling and 3 miles visibility and at or above 800 feet ceiling and 2 miles visibility.)

The conduct of formal Phase II operations was concluded on 1 March 1991. Tieing operations had been evaluated operationally for a total of 43 and 1/2 hours. The following week, the St. Louis Plans and Procedures Staff, supported by MITRE, presented formal questionnaires to those TRACON and tower controllers who had experience with the CRDA tieing function. The questionnaires focused on the CHI aspects of the CRDA tieing application and related workload considerations. The questionnaire responses were analyzed by MITRE and presented at the ORR held in St. Louis on 18 March 1991. As a result of that ORR, permission was given to St. Louis to begin Phase III operations (i.e., stagger operations during VFR weather conditions). However, for reasons to be discussed in section 5.3, the start of Phase III was delayed for six weeks, until 1 May 1991.

5.2.2 External Factors Affecting the Evaluation

Although completed successfully, Phase II operations and the associated evaluation were affected by outside influences which were beyond the control of the project. It was known in advance that certain traffic situations were desired in order to evaluate tieing most effectively. Specifically, the evaluation team was interested in periods where arrival demand was high enough to benefit from use of the additional converging runway, and where the departure demand was sufficient to determine whether the tieing application did, in fact, provide additional departure slots on runway 30R.

The most significant impact upon the evaluation was the decreased level of traffic, caused by a number of factors. Due to CRDA software development delays prior to the delivery of the CRDA software to St. Louis, the actual operational evaluation began during the winter, a time when traffic levels have been historically lower. Phase II had originally been scheduled for the summer months, when the typically heavier traffic load would have created a greater demand for the tieing function. The traffic level was also down during this period due to the Persian Gulf War, and the reluctance of individuals to conduct any non-essential travel. Finally, St. Louis is the hub airport for Trans World Airlines (TWA) and, because the country was in an economic recession, TWA and other commercial airlines had cut back their number of scheduled flights during this period.

In addition to the decreased traffic, the amount of CRDA testing was affected by the weather conditions at St. Louis during Phase II. The tieing function was designed to be operated when St. Louis is using parallel runways 30L, 30R and the converging runway 24 (the predominant runways). During much of Phase II, however, St. Louis had unusual wind conditions requiring unusually high utilization of runways 12L and 12R. The measured ceiling frequently fell below the minimum necessary to conduct tieing operations, further limiting the amount of time when St. Louis could conduct the tieing evaluation.

During a Project Management Review held during Phase II, the option of extending the Phase II evaluation in order to obtain additional controller experience in bona fide tieing situations was discussed. This alternative was rejected since it was felt that this would result in a schedule delay for the St. Louis evaluation, potentially affecting the national implementation of CRDA. It was also felt that the delay would not be justified in terms of the impact the additional experience would have on the ultimate controller evaluations of the aid. While there were fewer opportunities than expected to use CRDA during Phase II, it was decided that the controllers did get sufficient experience with the program to be able to adequately evaluate its CHI and its affect on their workload. However, due to the limited amount of CRDA use, the originally-planned collection and analysis of continuous data recording (CDR) information (see reference 7) was deleted from the evaluation for Phase II.

As a result of the external factors which affected the conduct of the Phase II evaluation, a significant lesson was learned regarding the conduct of operational evaluations under actual field conditions. While a well-thought-out OEP is essential prior to the start of the operational evaluation, it sometimes becomes necessary to deviate from the plan as the evaluation proceeds. Good project management mechanisms should be used to permit informed decisions to be made as to when to adhere to the original evaluation plan and when deviations from the original plan become both necessary and justified. When unexpected conditions arose in Phase II, the CRDA project management team was able to modify the original evaluation plan, while still maintaining the integrity of the evaluation results.

The actual evaluation performed and its general results are described in the following section. Copies of the actual questionnaires used and detailed results are presented in appendix B. When reviewing the evaluation results, the reader is cautioned to keep in mind the fact that

the questionnaire results were based on less than optimal controller experience with the tieing application. Since the evaluation phase described in this report, St. Louis had numerous opportunities to use CRDA tieing during their regular operations, and under traffic conditions for which the tieing application is intended. The results obtained during that time continued to support the evaluation of the CRDA tieing aid.

5.2.3 Evaluation Performed and Results

The CRDA tieing function was evaluated both formally and informally. The informal evaluation consisted of observing the controllers while using the CRDA aid to determine how accurately and consistently the controllers were able to tie arrivals to runways 24 and 30R. The formal evaluation consisted of administering formal controller questionnaires and analyzing the results.

Although several new findings arose as a result of the formal evaluation, for the most part, the formal evaluation confirmed the observations made during the informal "day-to-day" evaluation by the St. Louis and MITRE staff. In general, the controllers were satisfied with the aid and felt that it enabled them to improve their job performance. General results are presented in this section, and detailed results of the tieing questionnaire are presented in appendix B.

Thirty-one TRACON controllers, including five supervisors and one Traffic Management Coordinator, were given the questionnaire, and all responded. The respondents had an average Full Performance Level (FPL) experience of approximately 5 years at St. Louis. About half the respondents indicated that they had less than 2 hours experience with CRDA, with the remainder indicating between 2 and 10 hours experience. Twelve tower controllers and 3 tower supervisors were given the questionnaire, and all responded. Those respondents had an average FPL experience of approximately 3 years at St. Louis. They all had limited exposure to CRDA tieing.

The respondents were instructed not to discuss the questionnaires among themselves while they were filling out the forms, to insure the integrity of the responses. The purpose of the questionnaires was discussed and the controllers were encouraged to ask for clarification of any of the questions as needed. The questionnaire responses were subsequently analyzed by MITRE.

As a result of the analysis of the questionnaire responses it was concluded that the CRDA CHI was suitable for controller use. The questionnaire results were so consistent that, in MITRE's view, it was unlikely that this general conclusion would have changed, even if a more extensive tieing evaluation had been conducted.

In general, there was consensus among the TRACON controllers as to their opinions about CRDA tieing. It was the unanimous opinion of the responding TRACON controllers that the ghost data block should not be changed and that the display of ground speed in the ghost data

block was operationally acceptable (most controllers did not choose to suppress the display of ground speed). Most of the responding TRACON controllers (i.e., ~ 94 percent) had no difficulty in distinguishing between ghost targets and actual aircraft. Most of the responding controllers (i.e., ~ 94 percent) did not consider clutter due to ghosting a problem; or felt that the ghost data blocks did contribute to display clutter, but that the overall assistance provided by CRDA during tieing operations outweighed the disadvantages presented by clutter. Most (i.e., 75 percent) of the responding TRACON controllers felt that the ghosting region should be widened and raised in altitude in order to eliminate situations where the ghost might appear too late for them to properly exercise speed or vectoring control, if needed.

There were other significant TRACON controller comments which came out of the formal evaluation. The controllers differed in their opinions as to how essential CRDA was in providing accurate ties over a sustained period of time; however no controller reported that CRDA hindered his/her ability to tie aircraft on runways 30R and 24. While most TRACON controllers felt that CRDA did not affect their other controller tasks, some mentioned occasional interference, primarily during periods of heavy traffic to satellite airports. Finally, the controllers differed on the degree to which wind conditions affected their ability to accurately tie, but all felt that with some effort satisfactory ties could be achieved regardless of winds.

For the most part, the tower controllers agreed on their evaluation of CRDA tieing. They all felt that there was some operational benefit to tieing with CRDA. Most of the responding tower controllers (80 percent) indicated that there was no difficulty in distinguishing between ghost targets and actual aircraft, and 2 of the 3 controllers who indicated some difficulty responded that it occurred "very rarely". Given that the facility was required to tie 30R and 24 arrivals, most (~ 87 percent) felt that the local controller's job was made easier using the automated CRDA tieing aid, as opposed to trying to tie manually. About 67 percent of the tower controllers responded that the local controller had to intervene "occasionally", by using speed or vector commands, in order to achieve an appropriate tie. Finally, the tower controllers almost unanimously felt that the Digital BRITE adequately presented ghost target data, but were looking forward to the enhanced DBRITE map capabilities (e.g., improved resolution) scheduled to be implemented in the near future.

There were two tower controller concerns expressed during the formal CRDA evaluation. A concern was expressed as to the adequacy of Tower/TRACON coordination in initiating tieing operations and during such operations. For example, if the Tower had a significant number of departures to get out, tower personnel needed to let the TRACON know that it might be an appropriate time to begin tieing operations. Conversely, when the TRACON initiated the tieing operation, the Tower needed to be notified so that manual action could be taken to display the ghost targets in the Tower. Concern was also expressed about the appropriateness of using a 1/2 mile offset in creating departure slots on 30R. Although the 1/2 mile offset, which the controllers were trained to use, was derived based on analysis of

St. Louis operational requirements, during actual operations some controllers felt that it would be easier, and require less attention, to put the target directly over the ghost[6].

Analysis of the St. Louis controller responses to the TRACON and tower questionnaires resulted in several recommendations regarding the implementation of CRDA tieing in the St. Louis TRACON and Tower. The immediate recommendation for the TRACON involved the widening and heightening of the ghosting region. Before operationally implementing that change, however, ETG testing should be performed with several scenarios to determine the appropriate limits to use.

The following TRACON-related recommendations were made as a result of feedback from St. Louis air traffic controllers and subsequent analysis by MITRE personnel. They were intended for implementation at some later date, when traffic demand and weather would permit more sustained use of tieing operations:

- Emphasize the need for the 30R controller to establish a final stream of traffic with consistent spacing. By setting up an established stream on 30R, it becomes easier for the 24 controller to place his/her aircraft with greater accuracy. Also, continue to emphasize the need for the 30R controller to enter timely assigned runway information into the scratchpad to ensure that the 24 controller can see the ghosts.

- Continue to monitor closely the workload of the 24 final controller during tieing operations. Evaluate whether it is necessary to split the position, especially when there is a high level of VFR traffic to the satellite airports. (Note: At the time of issuance of this interim report, St. Louis has not yet felt a need to split this position, although this remains a viable option if traffic levels increase.)

- Keep track of potential problems with clutter. If it is determined that clutter is a CRDA problem, ascertain the traffic level at which clutter problems begin. (Note: With ARTS IIIA, Version 3.05, individual leader offset control will be provided, and St. Louis intends to reevaluate this area when that capability is available.)

- Further evaluate the effect that wind conditions have on the ability to achieve accurate ties. Determine whether there are any specific wind conditions which should preclude use of tieing. Facilitate information exchanges between controllers to determine the most effective techniques to compensate for difficult wind conditions. (Note: At the time of issuance of this interim report, St. Louis has not identified any wind conditions which would preclude the use of CRDA-assisted tieing. The facility plans to continue evaluating this area on an ongoing basis.)

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6 The controllers were trained to provide a 1/2 mile offset for tieing since, if running with minimum spacing between departures on 30R, a tie which is "too good" could lead to insufficient separation between a departure from 30R and an arrival to runway 24.

The tower-related recommendations were to develop more explicit tower/TRACON coordination procedures for use during CRDA tieing operations and to reevaluate whether the 1/2 nmi offset rule is still appropriate. Recommendations for improving coordination included having the tower inform the TRACON when tieing is needed and when it can be discontinued. In turn, the TRACON needs to make sure that the tower knows when CRDA is activated so the Quick Look function can be used to display ghost targets on the tower DBRITE. Further, the tower needs to provide feedback to the TRACON as to the accuracy of the ties, so it can be determined whether compensation is needed for winds or other factors.

The improved coordination mechanisms were in fact adopted by St. Louis, and they have led to improved transitioning into and out of tieing operations, and improved tieing accuracy during operations. Regarding the 1/2 nmi offset rule for tieing, St. Louis has concluded that (1) it needs to be applied only in certain operational situations (i.e., when running with minimum spacing between departures on runway 30R), and (2) when the rule is used, a 1/2 nmi offset is appropriate during calm wind conditions, but it may need to be adjusted to accommodate other wind conditions.

As mentioned in section 5.2.2, St. Louis had numerous opportunities to use CRDA tieing operations after the Phase II evaluation was officially concluded. As a result of the use of the tieing version of the CRDA program during routine operations, St. Louis repeatedly reported that the tieing aid works as intended. *St. Louis Air Traffic personnel report that* CRDA tieing does, in fact, provide extra departure slots on runway 30R during heavy arrival demand periods, while also making the converging runway 24 available for arrival traffic.

5.2.4 Results of the ORR

An ORR was held in St. Louis on 18 March 1991, following the conclusion of the CRDA Phase II operational evaluation, to determine whether St. Louis was ready to start the Phase III evaluation. Represented at the ORR were St. Louis Tower, the CRDA Program Office, ATR-210 and ATR-400, FAATC ACD-305 and ACD-340, ASC-200, Air Traffic Training (ATZ)-100, MITRE, and Computer Technology Associates (CTA).

St. Louis reviewed Phase I of the evaluation (ETG Training) and presented the informal results of the Phase II evaluation. MITRE presented the results of the formal Phase II evaluation, which were consistent with and supported the informal evaluation findings. There was a general consensus of support for the findings from those present at the ORR.

As a result of the ORR, authorization was given to start Phase III of the CRDA evaluation on 1 May 1991. This start date for the evaluation of VFR stagger operations reflected a delay of six weeks from the original start date. The reasons for this delay are described in section 5.3.

St. Louis was also authorized to continue performing CRDA tieing operations when warranted by traffic levels, weather, and operational conditions at the airport.

5.3 PHASE III: STAGGER OPERATIONS IN VFR

5.3.1 General

At the ORR of 18 March 1991, which concluded Phase II of the evaluation, St. Louis was authorized to begin Phase III of the evaluation -- stagger operations in VFR -- effective 1 May 1991. The originally planned length of time for Phase III was also extended by about two weeks (from 62 days to 79 days) to permit more time for acquiring controller experience in the use of the CRDA during VFR stagger operations. During the six week period between the ORR and the start of Phase III, St. Louis undertook several activities to prepare for Phase III. These activities included the following:

- ETG refresher training on staggering for supervisors and controllers (conducted between 8 April and 19 April), to include orientation with a new airspace structure developed by the Facility Advisory Board (FAB) at St. Louis for use during staggering operations

- Production and installation of new video maps for the new airspace design associated with CRDA

- Development of a plan for "managing the system" in order to minimize delays to the users during VFR stagger operations while providing adequate opportunities for the St. Louis controllers to become proficient with the stagger application of the CRDA (further details on this are provided in section 5.3.2)

- Coordination with the local St. Louis community, since the new airspace changes would affect the noise-sensitive localities underlying the final approach courses of Runways 24 and 30R

- Creation of training videotapes for ad hoc review of the CRDA procedures and airspace by tower and TRACON controllers

The principal objective of Phase III was to provide an opportunity for St. Louis controllers to obtain adequate experience in stagger operations during VFR conditions when the tower could provide visual separation prior to the loss of standard radar separation. During Phase III, both the procedures for using DCIA and the operation of the CRDA program were evaluated. The evaluation objectives for this phase were to:

- Determine the suitability of the CHI for stagger operations, for both the TRACON and tower controllers

- Verify the suitability of related TRACON/TRACON and TRACON/tower coordination procedures during stagger operations, and refine them as necessary

- Begin to determine the impact of staggering on departures during "IFR-like" arrival/departure traffic demand periods. That is,

  -- Determine if departure delays are a problem, and if so, under what conditions

  -- Identify and evaluate strategies for dealing with departures while still maintaining arrival benefits

  -- Determine and validate the optimal arrival/departure strategy during stagger operations

The overall approach to the Phase III evaluation was as follows:

- Introduce VFR stagger operations gradually, using weather step-down criteria

  -- Begin with "clear conditions" (per reference 6), defined by St. Louis as a ceiling ≥ 1500 feet and a visibility ≥ 4 miles

  -- After initial experience had been gained with 1500 feet/4 miles, then step down to basic VFR conditions (1000 feet and 3 miles) (timing of this step down was a joint decision between St. Louis and the Central Region; authorization to step down was given on 10 June, and first actual use of 1000 feet/3 miles occurred on 25 June 1991)

- Focus initially on the use of staggering during "arrival only" periods (i.e., periods with only a light departure demand)

- Address impact on departures during heavy "IFR-like" arrival/departure periods afterwards

- Minimize delays while acquiring stagger experience in VFR conditions

  -- If possible, pick "IFR-like" arrival demands

  -- Have the TMC monitor departure delays and discontinue arrival stagger operations as necessary to clear out departure queues

- Delay the commencement of the "formal" portion of the evaluation (see next paragraph) as long as possible to capitalize on controller proficiency and experience

The evaluation methods which were to be used during the formal portion of the Phase III evaluation consisted of:

- The administration of a questionnaire to the TRACON and tower controllers to determine the suitability of the CHI and coordination procedures associated with stagger operations

- The collection and analysis of Continuous Data Recording (CDR) data during periods of stagger operations to confirm that the controllers, with the assistance of CRDA, could achieve consistent and accurate staggers

Actual VFR stagger operations with CRDA began on 1 May 1991, and continued until 6 August 1991. As mentioned above, the primary objective of this phase was to develop a level of controller proficiency with CRDA-assisted stagger operations prior to conducting such operations in IFR conditions. However, due to the factors described in the next section, the opportunities for using the CRDA for staggering in VFR conditions were not as numerous as expected, and it was not practical to achieve the level of controller experience during this phase that was originally planned. This led to the need to modify the evaluation plan so that the evaluation could proceed to Phase IV without compromising in any way the safety of the overall CRDA evaluation, or compromising the evaluation objectives of Phase III. The modified approach to the evaluation is described in section 5.3.3, and the results of the Phase III evaluation are described in section 5.3.4.

5.3.2 External Factors Affecting the Evaluation

There were several factors beyond the control of the CRDA project which resulted in fewer opportunities to use stagger operations during Phase III than was originally hoped for and planned upon. These are discussed in the following paragraphs.

5.3.2.1 Generally Unfavorable Weather Conditions

In general, weather conditions during the Phase III evaluation period did not permit the use of CRDA VFR stagger operations to anywhere near the extent that was expected. For example, the use of staggering was virtually precluded during the entire month of May due to an unusual, prevailing wind pattern which required the use of the runway 12 arrival configuration, rather than the runway 30 configuration required for the CRDA evaluation. This wind pattern permitted the use of CRDA for stagger operations for only four hours during the entire month of May. While the weather conditions for the remainder of Phase III were somewhat more cooperative than in May, conditions were still generally unfavorable, and, coupled with the problem discussed in the next section, opportunities for use of VFR staggering were very limited.

5.3.2.2 Unacceptable Arrival Traffic Delays

When the plan for the operational evaluation of CRDA at St. Louis [reference 7] was first formulated in late 1990 and early 1991, it was already known that the use of stagger operations in VFR weather conditions would have an adverse impact on St. Louis arrival operations and user delays. However, it was felt at the time, and St. Louis personnel agreed, that this penalty was unavoidable to achieve the goals of Phase III of the evaluation. The basic problem was that the stagger operation is an IFR procedure, which uses IFR-based separation criteria (i.e., stagger distances), and St. Louis can land more aircraft in VFR conditions if there is heavy arrival demand when VFR landing procedures are used.

The fact that arrival delays could be expected was addressed in the original operational evaluation plan [reference 7], along with a description of the general method for controlling such delays. From the start of Phase III, however, St. Louis began reporting that arrival delays would be greater than originally expected, and that such delays could not be tolerated by the facility. Contributing to the higher-than-usual level of intolerance for arrival delays was the fact that the U.S. economy was in a recession at the time, and most airlines, including TWA (by far the principal air carrier at St. Louis), were operating with substantial financial losses; hence, fuel, crew, maintenance, and other operating costs were under extreme scrutiny by the airlines.

In order to attempt to achieve a reasonable level of controller experience with staggering, and yet greatly minimize arrival delays, CRDA personnel at St. Louis attempted to identify "arrival only" (i.e., minimum departure) periods when CRDA could be run in the VFR stagger mode without "backing up" the system and causing unacceptable arrival delays. This included attempts to perform evaluation on the weekends, but unfortunately unfavorable weather or other factors usually precluded success during weekends. Several "arrival rush" periods were tried during the week, but this normally resulted in unacceptably high delays. Toward the end of Phase III, St. Louis attempted to increase the number of VFR stagger operations by using CRDA during an early morning (approximately 6:45 a.m.) arrival rush, but this could only be done on a limited basis due to local community noise sensitivity considerations. Also, this morning rush generally did not generate enough traffic to build the 30R arrival stream out far enough to support stagger operations.

Due to the arrival delay constraints which applied, compounded by the generally unfavorable weather which prevailed during Phase III, VFR CRDA-assisted stagger operations were conducted for only 10 hours (specifically, 9 hours and 59 minutes) during Phase III. This included the staggering of at least 165 aircraft during Phase III; the total number of operations is not known, since prior to 20 June, St. Louis kept track of VFR stagger use in terms of time, while after 20 June, both the duration of stagger operations and the number of staggered aircraft were recorded and reported.

5.3.3 Modifications to the OEP

The limited, initial use of CRDA-assisted stagger operations conducted during Phase III provided a preliminary indication, based on informal reports from St. Louis, that the aid could be used by the controllers to achieve accurate and consistent staggers. However, since it was not possible during Phase III to provide an adequate number of opportunities for the St. Louis controllers to develop a sufficient level of experience with CRDA-assisted stagger operations, the decision was made to modify the operational evaluation plan as follows:

- Defer the administration of the CRDA stagger questionnaire for tower and TRACON controllers until Phase IV, so the controllers could acquire a higher level of experience with CRDA in stagger operations
- Delete Phase III plans to collect and analyze CDR stagger data; defer this activity to Phase IV, scale it back in magnitude (i.e., decrease the number of operations for which data would be recorded and analyzed), and complement this activity with a structured, more extensive manual observation approach to determine the consistency and accuracy of the staggers (this is explained further in section 5.4)
- Defer until Phase IV the evaluation of the impact of stagger operations on departures during overlapping arrival/departure rushes

Note that with these modifications to the evaluation plan, all of the originally intended Phase III objectives of the plan would still be accomplished, but somewhat later in the evaluation than originally planned.

It was also decided to augment the evaluation with several safety-oriented activities to assure that safety would in no way be compromised by proceeding to Phase IV (i.e., stagger operations in IFR conditions) without developing more controller experience and proficiency with CRDA-assisted stagger operations in Phase III. These additional evaluation activities are described in the next section.

5.3.4 Safety-Related Activities and Considerations Prior to Proceeding to Phase IV

While the principal evaluation objectives originally planned for Phase III could be deferred to Phase IV, as explained in section 5.3.3, the question of whether it was absolutely safe to proceed to Phase IV had to be addressed before that portion of the evaluation could commence. This section summarizes those activities undertaken to provide that assurance.

5.3.4.1 Simulation Analysis of Consecutive Missed Approaches for St. Louis

At the request of the CRDA Program Office (ARD-40), MITRE developed a computer simulation to assess the spatial and time separation at the projected runway intersection of runways 30R and 24 in the case of consecutive missed approaches during dependent

converging instrument approach operations at St. Louis. The simulation was developed according to a test plan developed by MITRE [reference 9], and the simulation tests and associated analysis was performed using St. Louis geometry, traffic mix, and procedures. The specific scenarios to be evaluated by means of the simulation analysis were defined in the test plan and coordinated with the principal FAA organizations associated with the CRDA evaluation. This minimum set of essential scenarios focused on worst case conditions involving such factors as (1) large speed differentials between the pair of aircraft executing converging approaches, (2) adverse wind conditions, (3) early and late execution of the missed approach, and combinations of these factors.

Reference 10 describes the definition and methodology used to develop the missed approach model; the determination of aircraft performance data used in the model; the validation and verification of the simulation; and the detailed results produced by the model for the agreed-upon scenarios and other scenarios of interest.

The principal result of the missed approach simulations indicated that for combinations of commercial aircraft there was no separation problem at the point of the intersecting flight paths, regardless of the runway assignment, should the consecutive aircraft miss their approach when staggered by the proposed minima of 2 nmi for non-heavy leading aircraft, and 5 nmi for heavy leading aircraft. However, the simulation showed that in cases wherein the leading aircraft was a very slow, low performance aircraft (i.e., single engine general aviation aircraft) approaching runway 30R, and the trailing aircraft was approaching runway 24 at a significantly higher speed, then a separation problem could exist at the intersection in the case of consecutive missed approaches.

The results of the simulation of consecutive missed approaches at St. Louis were used as input to developing the CRDA test waiver for the St. Louis evaluation. It was originally hoped that a stagger of 2 nmi for a leading non-heavy aircraft and 5 nmi for a leading heavy aircraft could be used in an unqualified sense, meaning that there would be no CRDA or DCIA-related restrictions regarding aircraft types which could be landed on either runway 24 or 30R. However, as mentioned above, the simulation results showed that certain speed differentials between aircraft approaching the converging runways could result in less-than-adequate separation at the projected runway intersection in the unlikely, but possible, case of consecutive missed approaches. After discussions between St. Louis facility personnel, FAA Headquarters representatives from Air Traffic Procedures and Flight Standards, and MITRE, the following qualifiers were included in the St. Louis test waiver to accommodate the findings of the simulation results (see items 11, 12, and 13 of the "Special Provisions, Conditions, Limitations" section of the St. Louis waiver contained in appendix C):

- All single engine or non-turbo twin engine aircraft shall utilize runway 24

- All heavy aircraft shall utilize runway 30R

- Aircraft with final approach speeds greater than 150 knots are not authorized to participate in the DCIA procedure.

The development of the missed approach simulation for St. Louis, and the evaluation of the simulation results, was performed under the independent oversight of FAATC ACD-340, as requested by the CRDA Program Office. Technical meetings were held between MITRE personnel and ACD-340 representatives throughout the development of the simulation and during the analysis of the simulation results. The simulation model was also made available to ACD-340 so that independent executions of the model could be made by ACD-340 in performing their oversight role. At the conclusion of the oversight task, ACD-340 published a report [reference 11] which indicated that the oversight team felt that MITRE had used a sound methodical approach for the Missed Approach Test Plan, as well as for the design of the simulation model, and that there were no significant problems or issues that the oversight team felt would require further attention.

5.3.4.2 Live Missed Approach Flight Demonstration

At the request of Air Traffic Procedures (ATP) and Flight Standards (AFS), the CRDA Program Office arranged to conduct a live demonstration of consecutive missed approaches in VFR conditions at St. Louis. The principal objective of the flight demonstration was to establish an FAA level of confidence that if two aircraft did, in fact, execute consecutive missed approaches to runways 24 and 30R during CRDA-assisted DCIA operations, adequate separation would exist at the projected runway intersection presuming the two aircraft executed their missed approaches according to published procedures. A secondary objective was to compare the actual distance and time separation from the live demonstration with those predicted by the missed approach simulation to determine the degree to which the actual and predicted values correlated.

The flight demonstration took place at St. Louis on Sunday, 28 July 1991. The demonstration was conducted according to a flight demonstration plan which was developed by MITRE (see appendix D). The aircraft and pilots were provided by the Wetterau Corporation and Emerson Electric. There was one practice flight, followed by four "real" flights. The aircraft used during the flight demonstration were a Beech King Air (twin turbo) and a Falcon-90 (jet), with each emulating various types of aircraft in terms of approach speeds and speeds and flight profiles during a missed approach. The four "real" flights which were conducted were as follows:

- Scenario #1: The Beech King Air emulated a heavy aircraft (i.e., a B767) leading and landing on runway 30R. The Falcon, emulating a Merlin, was the trailer approaching runway 24, and it was staggered by 5 nmi.

- Scenario #2: This scenario had each aircraft performing as it normally would for its actual aircraft type (i.e., no emulation of another aircraft type). The King Air was the

leading aircraft and was approaching runway 30R; the Falcon was the trailing aircraft approaching runway 24. The stagger was 2 nmi.

- Scenario #3: This scenario was planned to be the most stressful, in the sense that it would result in the smallest separation at the intersection. The King Air emulated an ATR-42 leading on 30R, and the Falcon was emulating an L1011 as the trailing aircraft approaching runway 24. The stagger was 2 nmi. (Note: This case was run to validate the simulation analysis recommendation that all heavies should be assigned to runway 30R.)

- Scenario #4: The King Air, emulating an ATR-42, was the leading aircraft and was approaching runway 24; the Falcon was staggered at 2 nmi and was emulating a B727 approaching runway 30R as the trailer.

The results of the four demonstration flights are summarized in the table below. In the "Separation" column, the "Actual" separation is that separation actually observed/measured during the flight; the "Expected" separation is that separation which was predicted by the missed approach simulation model.

Table 5-1 Flight Demonstration Results

Scenario	Leader		KingAir	Trailer		Falcon	Separation	
	AC Type	FAS*	Runway	AC Type	FAS*	Runway	Expected	Actual
1	B767	125	30R	Merlin	140	24	104 sec	108 Sec
2	KingAir	105	30R	Falcon	130	24	1.68 nmi	1.6 nmi
3	ATR42	110	30R	L1011	135	24	1.32 nmi	1.4 nmi
4	ATR42	100	24	B727	140	30R	-	1.8 nmi

* Final Approach Speed

For scenarios 1, 2 and 3, note the extraordinarily close results between the actually observed/measured data and the separation as predicted by the missed approach simulation model. During the fourth demonstration flight, the King Air pilot (who was in the leading aircraft) deviated from the script and executed his missed approach at a faster speed than was planned. For this case, there was insufficient data to execute the missed approach simulation model for comparison purposes.

Both objectives of the live flight demonstration at St. Louis were successfully met. The exercise enhanced the FAA's confidence level in proceeding to Phase IV of the evaluation in two ways: first, the demonstration did show that adequate separation would be achieved in the case of consecutive missed approaches, at least for the four representative cases which were run; secondly, the extremely close correlation between the actually observed/measured

separations and those predicted by the missed approach simulation model increased the FAA's confidence in the credibility of the simulation.

5.3.4.3 CRDA Users Conference

On 23 August 1991, the FAA conducted a users conference in Washington, D.C., on DCIAs and on the planned use and evaluation of such procedures at St. Louis using CRDA in IMC. The purpose of the conference was to (1) inform the users of FAA's plans for the use and evaluation of CRDA-assisted DCIAs at St. Louis and (2) solicit user support for the program. In attendance at the users conference were representatives from the Air Transport Association (ATA), the Airline Pilots Association (ALPA), the Regional Airlines Association (RAA), and the National Business Airlines Association (NBAA).

At the conference the users were presented briefings in the following subject areas:

- DCIAs -- Description of DCIAs, rationale for their need, analysis related to stagger distances chosen for the evaluation at St. Louis, analysis of time and spatial separation in the case of consecutive missed approaches to the converging runways 30R and 24.

- Evaluation approach and operational procedures -- Evaluation phases used at St. Louis, operational implications, and expected benefits from the use of CRDA-assisted DCIAs.

- Results of the flight demonstration conducted at St. Louis on 28 July, including a short briefing by Joe Lintzenich, Chief Pilot of Wetterau, on his perspective as a participant in the flight demonstration.

After these briefings were presented, the floor was open for general discussion. Particularly noteworthy was the fact that no questions arose regarding the safety of the DCIA operation, and no user concern was expressed related to proceeding to Phase IV of the CRDA evaluation at St. Louis. Rather, most of the discussion focused on other possible applications of the "ghosting" concept, and the need, expressed by the users, for expeditious fielding of the CRDA at other airports.

5.3.4.4 Other FAA Safety Initiatives Prior to Phase IV

In addition to the missed approach safety analysis described in section 5.3.4.1, and the live flight demonstration described in the previous section, the FAA undertook several other initiatives to further insure that the CRDA Phase IV operations and the associated evaluation would be conducted with a high level of safety. These initiatives included the following:

- Use of a dedicated monitor position -- From the beginning of the planning for the CRDA operational evaluation, St. Louis stated an intention to use a final monitor

controller during CRDA stagger operations in IFR. The final monitor would be located in the tower, and would be designated as the LC-3 position. This controller would coordinate with the LC-North (LC-N) position, as necessary, to assure that at least the minimum stagger was achieved. LC-3 would also have a frequency override capability of the LC-N frequency for direct intervention if needed. St. Louis' plan was to use this final monitor position for as long as necessary; i.e., if after some period the position appeared to be unnecessary, then it would no longer be staffed. However, due to the limited controller experience with stagger operations in Phase III, FAA Headquarters suggested that the final monitor position be staffed during IFR stagger operations for the duration of Phase IV, and St. Louis agreed.

- Use of weather step-down criteria -- As a further safety precaution, FAA Headquarters and the Central Region recommended that Phase IV operations be conducted according to specific weather step-down criteria; i.e., a certain number of operations would need to be successfully accomplished at high IFR weather conditions before proceeding to stagger operations at the next step-down level. This step-down process would continue until CRDA stagger operations at Category I weather minima were reached. For each step-down level, approval by the Central Region would be required prior to St. Louis conducting stagger operations at that level.

An important factor considered prior to deciding whether or not to proceed to Phase IV was the comfort level of the St. Louis facility. Facility management indicated that they were comfortable with proceeding to Phase IV for the following reasons:

- The controllers had received extensive ETG training on the use of CRDA for staggering. They received initial training in January 1991, and later received refresher training during April.

- The controllers had developed extensive experience with the tieing application of CRDA, both as a result of the successful conduct of Phase II of the evaluation and due to the continued use of tieing in day-to-day operations after the conclusion of Phase II. St. Louis reported that it was very comfortable with the use of CRDA for tieing, and that their tieing experience had provided general experience with the ghosting features provided by CRDA.

- Staggered approaches are not unlike procedures used at St. Louis in VFR conditions prior to the introduction of CRDA, but now the controllers have the CRDA-generated ghost to aid them in more precise staggering required for IFR operations.

5.3.5 Results of the ORR

An ORR was held in St. Louis on 20 August 1991 to determine whether Phase IV of the CRDA evaluation should be authorized to commence. Represented at the ORR were St. Louis Tower, the CRDA Program Office, Air Traffic Management (ATM)-120, ATR-210, ATR-400, ATP-120, the Central Region, FAATC ACD-340, Philadelphia Tower, St. Louis Flight Service District, MITRE, and CTA.

St. Louis and MITRE representatives reviewed the Phase III evaluation activities, the missed approach simulation analysis, and the missed approach flight demonstration results. MITRE also presented a briefing on the evaluation activities to be conducted in Phase IV, presuming a decision was made to proceed to Phase IV.

As a result of the ORR, authorization was given to start Phase IV of the evaluation, effective 1 September, presuming that (1) the CRDA Users Conference scheduled for 23 August was successful (which it was -- see section 5.3.4.3) and (2) coordination of the St. Louis test waiver was completed and the waiver was signed (which it was, on 3 September).

During the ORR, a set of weather step-down criteria was proposed by St. Louis representatives, and the Central Region agreed to review the proposed criteria and to advise St. Louis and other project participants of the approved step-down criteria (the approved criteria are addressed in section 5.4). The coordination mechanism between St. Louis, Central Region, and Headquarters for implementing the weather step-down process was also defined during the ORR.

5.4 PHASE IV: STAGGER OPERATIONS IN IFR

5.4.1 General

5.4.1.1 Chronology of Events

Phase IV of the CRDA evaluation, the conduct of stagger operations during IFR weather conditions, was authorized to start on or after 3 September 1991. A DCIA waiver was issued which authorized the St. Louis Airport Traffic Control Tower to conduct DCIA approaches and to operate CRDA in IFR weather for a period of two years. Phase IV was to be conducted according to weather step-down criteria, and these criteria were documented in a memorandum issued on 5 September 1991 by the manager of the Air Traffic Division, ACE-500. Although a step-down approach utilizing aircraft separation had also been discussed, it was not made a requirement of Phase IV.

Specifically, St. Louis was authorized to conduct DCIA approaches and to operate CRDA in less than VFR, but not less than a 700 foot ceiling or 2 miles visibility, until they had recorded 125 staggered approaches to runway 24. Written authorization by the Manager, Air

Traffic Division, ACE-500 would be required prior to proceeding to each step-down level. On 29 January 1992, the Manager of the St. Louis ATCT submitted a CRDA IFR Stagger Summary Log to the Central Region. That log documented the operation of CRDA stagger with over 125 approaches to runway 24 in weather conditions between 1000-3 and 700-2.

On 6 February 1992, St. Louis war authorized to continue testing CRDA stagger in weather down to a 500 feet ceiling or 3/4 mile visibility. Following the completion of 75 approaches to runway 24 during the operation of CRDA stagger with weather between 500-3/4 and 700-2, the Central Region would again determine whether St. Louis could proceed to the next step-down level. On 27 February 1992, St. Louis met those performance requirements and submitted another CRDA IFR Stagger Summary Log to the Manager, Air Traffic Division, ACE-500.

Per the original step-down plan, after St. Louis had successfully demonstrated that it had handled 200 operations during the first two step-down periods, and with ACE-500's approval, St. Louis would be allowed to proceed to the final CRDA evaluation step. Another condition required by the Central Region, before proceeding to the last step, was that ETG sessions must have been given to all control personnel and all crews had been exposed to IFR stagger at least once.

On 11 March 1992, St. Louis was authorized to continue testing CRDA in weather down to a 200 feet ceiling or 3/4 mile visibility. This was the final step-down level to be evaluated. The Region defined the step-down requirements for this level to be the conduct of 25 operations at or below 300 feet <u>and</u> at or below 1 mile visibility. Note that because ILS approaches to runway 24 are not permitted when the ceiling goes below 250 feet, it was the effective ceiling minimum for this step. Since weather ceilings are measured in hundreds of feet, this therefore meant that St. Louis was required to record a minimum of 25 approaches in weather conditions at 300 feet above ground level <u>and</u> at or below 1 mile visibility in order to complete the CRDA evaluation. Although all crews had not yet been exposed to CRDA stagger, that original prerequisite was modified to permit those crews with experience to operate CRDA under the final step-down weather criteria.

It was recognized by all parties involved in the evaluation of DCIA procedures and the CRDA program, that given the time of year, it was unlikely that St. Louis would have sufficient IFR weather to be able to complete the evaluation before the succeeding fall at least. At this point in time, the final step-down of the evaluation has not been completed. However, it was felt that St. Louis controllers did have enough experience to provide a meaningful evaluation of CRDA stagger that could be used to guide the national implementation of CRDA. It was decided that a final evaluation would be completed once St. Louis has gotten enough experience utilizing CRDA at the worst allowable weather conditions. The results of that final evaluation will be provided at a later date in a separate appendix to this report.

5.4.1.2 Objectives

There were five objectives to be met by the Phase IV evaluation, several of which were originally planned for Phase III, but were deferred to Phase IV. Although the Phase IV evaluation will not have been completed prior to the publication of this report, much of what has been learned so far (via the formal and informal evaluations) enables most of the objectives to be satisfied.

The evaluation included an assessment of the CRDA CHI interface, the usefulness of the CRDA to the controllers, workload impact, and the adequacy of CRDA-related coordination procedures. Sufficient CRDA stagger experience was acquired during Phase IV to satisfactorily meet this objective.

Ability of the controllers to achieve consistent, accurate staggers

The evaluation needed to confirm the ability of the controllers to achieve desired stagger separations on a consistent basis. This ability was evaluated based on direct observations recorded via manually logged data, limited collection and analysis of CDR data, and informal controller feedback reported on questionnaire forms administered by St. Louis or recorded by the LC-3 controller on test worksheets administered by MITRE. Although Phase IV has not been completed, this report is able to address this objective given the data available from the first two step-down periods of CRDA stagger operations.

Assessment of arrival throughput increase

The Phase IV evaluation objectives included the comparison of "before CRDA" and "after CRDA" arrival throughput data to determine if throughput increases have been realized. The evaluation also included determining the magnitude of any increase in arrival throughput that was experienced during Phase IV. Sufficient data existed at the time of this report to successfully meet this objective.

Impact of staggering on departure operations

Another objective of Phase IV was to determine whether staggering arrival operations adversely affected departure operations to a degree unacceptable to St. Louis. If so, the best operational strategy for dealing with the departure problem would need to be determined. Although there was not enough data at the worst weather conditions to finalize the determination of the degree of the departure problem, this report evaluates the impact CRDA stagger had on departures where visual conditions still existed. Also, although a single strategy cannot be recommended at this time, potential alternative operational strategies which can be considered, following the completion of Phase IV, are addressed.

Assessment of the need for a CRDA monitor controller

The final objective of the Phase IV evaluation was to assess whether a CRDA monitor controller position should be a requirement of the national implementation of the program. Although a preliminary recommendation can be made, based upon the evaluation completed to date, that initial recommendation may need to be modified following the completion of Phase IV.

5.4.1.3 Prerequisites to Commencing Phase IV

In addition to establishing the step-down criteria and planning for the evaluation, other prerequisites needed to be met before Phase IV could proceed. The waiver authorizing St. Louis to conduct DCIAs in IFR weather needed to be signed. In addition, a Notice to Airmen (NOTAM) needed to be issued which informed the pilots of St. Louis' intent to conduct DCIAs in IFR weather. Finally, new DBRITE video maps needed to be created and installed in the Tower prior to the start of Phase IV operations.

The waiver permitting the St. Louis ATCT to conduct dependent converging instrument approaches using CRDA was signed on 3 September 1991 and is valid for a period of two years. The waiver/authorization are shown in appendix C. The NOTAM became effective on 22 July 1991. Finally, with the completion of the DBRITE video map installation on 10 September, St. Louis was ready to begin Phase IV.

With all prerequisites met, the start of the Phase IV evaluation required only the appropriate weather conditions. They included winds allowing utilization of the runway 30R/L and runway 24 configuration, a measured ceiling below 1000 feet but above 700 feet or visibility greater than 2 miles but less than 3 miles. With St. Louis approaching the winter season, it was hoped that favorable weather conditions would provide significant opportunities to utilize CRDA stagger.

5.4.2 External Factors Affecting the Evaluation

Phase IV of the CRDA evaluation proceeded more smoothly than Phases II and III. Inappropriate weather conditions was the only significant external factor which resulted in delaying the evaluation. Due to uncooperative weather, it took until 12 November 1991 before the first recorded arrivals using CRDA IFR stagger were logged. After that, however, it only took a little over two months to meet the first step-down requirement of 125 arrivals to runway 24. The 75 runway 24 arrivals required by the next step-down level were handled in under two weeks, during the period from 13 February and 24 February 1992.

Unfortunately, March and April weather was perhaps the fairest in St. Louis history -- great for the residents, but detrimental to the completion of the evaluation. It is now anticipated that final completion of Phase IV will not occur until at least some time in the fall of 1992.

5.4.3 Evaluation Performed and Results

The CRDA stagger function and DCIA procedures were evaluated both formally and informally. The informal evaluation consisted of observing the controllers while using the CRDA aid and manually logging arrival information in order to determine how accurately and consistently aircraft on runways 30R and 24 were being staggered. The informal evaluation also included a Tower log on which the LC-3 controller recorded the number of speed adjustments or other actions taken in order to insure separation standards would not be violated. The formal portion of the evaluation included the administration of tower and TRACON controller questionnaires, analysis of data to assess the magnitude of the arrival throughput increase attributable to CRDA, and an assessment of the impact of staggering on departure operations.

A summary of the evaluation results for each of the five Phase IV evaluation areas is presented in the sections below.

5.4.3.1 Suitability of the CRDA CHI Interface and Related CRDA Procedures

The administration of the CRDA stagger questionnaires to tower and TRACON controllers and supervisors was performed during the period 14 - 20 April 1992. During that period, representatives from the St. Louis Plans and Procedures Staff and MITRE met with those controllers, supervisors, and TMCs experienced with CRDA stagger. The respondents were instructed not to discuss the questionnaires among themselves while they were filling out the forms, to insure the integrity of the responses. The purpose of the questionnaires was discussed and the controllers were encouraged to ask for clarification of any of the questions as needed. The questionnaire responses were subsequently analyzed by MITRE.

The detailed results of the evaluation of the stagger questionnaires, and copies of the questionnaires administered to the controllers, are presented in appendix E. A summary of the results from the evaluation follows.

Twenty-three TRACON controllers, one TRACON supervisor, and one TMC were given the TRACON questionnaire and all responded. The respondents had an average FPL experience of approximately six years at St. Louis. Seventeen of the respondents indicated that they had more than 2 hours experience using CRDA for stagger operations, with only one respondent indicating less than 1/2 hour experience. Ten tower controllers, two tower supervisors, and one staff specialist responded to the questionnaire. The respondents had an average of six years experience certified as a local controller at St. Louis. Seven tower controllers indicated that they had between 1/2 and 2 hours experience at the local north (LC-N) position and eight indicated between 1/2 and 2 hours experience at the monitor (LC-3) position during CRDA stagger operations.

As a result of the analysis of the questionnaire responses, it was concluded that the CRDA CHI was suitable for controller use. No modifications to the CRDA CHI interface are

required for either the St. Louis version or the national version of CRDA stagger. The controller responses were so consistent in the area of the CHI that it is not anticipated that this conclusion will be affected by the completion of Phase IV.

The TRACON controllers had a consensus of opinion on most of the areas addressed by the questionnaire. Most (i.e., greater than 80 percent) of the respondents indicated that use of CRDA stagger did not affect the accomplishment of their other controller tasks, no additional information was required in the ghost data block, there was no difficulty distinguishing between ghost targets and actual aircraft, and use of the same ghost position symbol for tieing and stagger operations was satisfactory. Most of the respondents also indicated that they always use the display of ground speed in the ghost data block and that the display of ground speed was operationally acceptable. All respondents indicated that they were not affected by any changes or deletions of ARTS functions due to CRDA. Over 90 percent of the TRACON respondents either did not feel that the ghost data blocks significantly contributed to display clutter or that the assistance provided by CRDA stagger outweighed the disadvantages of the additional clutter.

The responding TRACON controllers did not reach consensus on whether CRDA was essential or merely very helpful to providing consistent and accurate staggers over a sustained period of time. The controllers split almost evenly on this question. They also disagreed on the degree to which adverse wind conditions affected their ability to achieve satisfactory staggers. 38 percent felt that winds were a factor but could easily be accommodated, while 50 percent felt that wind conditions could significantly affect their ability to achieve consistently accurate staggers. Two respondents reported that adverse wind conditions had sometimes prevented them from achieving required stagger separations. Finally, the TRACON respondents were almost evenly split as to whether the ghost targets were displayed at the right time or were sometimes displayed too late.

The tower controller questionnaires showed less consensus of opinion than did the TRACON surveys. However, most (i.e., greater than 85 percent) of the tower controllers responding to the questionnaire agreed that the DBRITE displays adequately presented ghost target data, and all but one respondent indicated that they had absolutely no difficulty in distinguishing between ghost targets and actual aircraft.

While the majority of tower respondents felt that Tower/TRACON coordination appeared adequate, four controllers indicated that coordination could sometimes be improved or needed to be improved. Their suggested areas of improvement are listed in appendix E. The tower controllers also had a divergence of opinion on the frequency with which they had to adjust the speed of staggered aircraft while working the LC-N position. While two controllers rarely or never intervened, about half of the remaining respondents intervened occasionally and the remainder intervened often. When assigned to the LC-3 position, about one fourth intervened rarely, one half intervened occasionally, and the remaining one fourth intervened often.

Several concerns were expressed by the TRACON respondents, in addition to the specific questions to which they were asked to respond. Several respondents indicated their opinion that the involvement of the TMC and the TRACON Supervisor for Arrivals (TSA) was crucial to the success of the transition into CRDA stagger and the establishment of traffic streams. Several respondents were concerned about the lack of frequency with which CRDA stagger was used and the difficulty in maintaining proficiency in its use.

Tower controllers expressed concern about the expected difficulties of departing aircraft during CRDA stagger operations, although due to limited usage during the worst weather conditions departure delays had not yet become a problem. They also mentioned the need for improved coordination with the TRACON on pullouts (i.e., aircraft broken out of the arrival stream) and wanted a better definition of pullout procedures. Tower controllers expressed concern about the adequacy of missed approach procedures to provide separation, the need for additional staffing, and the need for additional simulation training. Finally, the tower respondents, as with the TRACON respondents, were concerned about the infrequency of CRDA stagger operations and the difficulty in maintaining proficiency.

A summary of recommendations resulting from the evaluation of CRDA stagger questionnaires is presented below. The detailed recommendations are contained in appendix E. For the TRACON, the following recommendations were made for St. Louis:

- Emphasize the need for timely scratchpadding of the assigned runway, in order to alleviate the problem of late display of ghost data blocks,

- Continue operations during adverse weather conditions and defer the decision of whether to inhibit the use of CRDA stagger for certain wind conditions until more experience has been gained with the aid,

- Insure early involvement by the TMC and the TSA in the transition to CRDA stagger and subsequent establishment of arrival streams,

- Increase the opportunities for which CRDA stagger can be used and, if necessary, consider periodic proficiency training utilizing ETG.

These recommendations were also broadened and used as the basis for developing guidance material for the national implementation of CRDA.

For the Tower:

- For national implementation of CRDA, each site should consider assigning a monitor position until sufficient experience has been acquired with the stagger application of CRDA,

- For national implementation, each site should consider whether standard pullout procedures can be specified,
- At St. Louis, increase the opportunities for which CRDA stagger can be used and, if necessary, consider periodic proficiency training utilizing ETG,
- For national implementation, provide a similar degree of training for both the TRACON and tower controllers.

5.4.3.2 Ability of Controllers to Achieve Consistent, Accurate Staggers

In order to confirm that the controllers could achieve consistent staggers, manual logs were kept for all instances when CRDA stagger was used at St. Louis. All observations of pullouts and missed approaches, and the reason for the action, were recorded. Furthermore, a log was maintained in the tower of speed or other adjustments which had to be made by the tower in order to prevent aircraft from being pulled out of the arrival stream. Based on the analysis of the logs, it was concluded that the controllers were able to consistently meet stagger separation requirements.

CDR data was extracted and analyzed for several periods during which CRDA stagger was operational. Those analyses confirmed the ability of the controllers at St. Louis to achieve desired stagger distances on a sustained basis. However, because St. Louis has only had very limited exposure to CRDA stagger during weather conditions where the tower did not have visual contact with the aircraft, it is recommended that this objective be readdressed at the conclusion of Phase IV, when St. Louis will have experienced at least 25 arrivals to runway 24 where the ceiling was 300 feet or less and visibility was 1 mile or less.

5.4.3.3 Assessment of Arrival Throughput Increase

Another objective of Phase IV was to determine whether arrival throughput at St. Louis had increased due to CRDA stagger and, if so, the magnitude of that increase. MITRE analyzed St. Louis arrival data, both the arrival acceptance rate set by the TMC and actual arrivals recorded on the Daily Traffic Record, for the periods of time when CRDA stagger was operational and for periods of time when equivalent weather was experienced at St. Louis prior to the availability of CRDA stagger. The comparison of the "before CRDA" and "after CRDA" data shows that St. Louis experienced a significant increase in arrival throughput following the implementation of CRDA stagger. In order to demonstrate this increase a few examples were selected from the periods when CRDA stagger was run and are described below.

On 6 January 1992, St. Louis ran CRDA stagger during four consecutive arrival rushes. Weather conditions included a measured ceiling of 2000 feet and visibility of 2 1/2 miles and fog. During similar periods the previous year, St. Louis would have established an arrival rate of 36 aircraft per hour and the Kansas City Center traffic manager would have caused a

National Program to be put into effect to insure St. Louis was not given more flights than it could handle. During those times that St. Louis set a 36 arrival rate, actual arrivals were typically less than 36. Additionally, when the weather improved and St. Louis was able to raise the rate, there was usually a lag of one arrival rush before Kansas City could increase traffic to meet St. Louis' higher capacity.

While running CRDA stagger on 6 January 1992, during the same weather conditions which previously would have mandated a 36 arrival rate, the St. Louis TMC was able to set an arrival acceptance rate of 48. Kansas City Center did not need to effect a National Program. During the five hours that CRDA stagger was run, St. Louis actually landed 51, 38, 36, 32, and 46 aircraft per hour, an increase of 23 aircraft (approximately 5 aircraft per hour) from what would have been expected prior to the implementation of CRDA. Note that the arrivals during this five hour period constituted the total arrival demand on St. Louis. Very minimal arrival delays were incurred, and no flight cancellations were made. Had the arrival demand been greater, use of CRDA most likely would have permitted even more arrivals during this period. Also, given that with a 36 rate St. Louis usually landed less aircraft, the actual increase in throughput was most likely even greater.

Significantly, very minimal arrival delays were experienced during this time period on 6 January . In similar periods before the implementation of CRDA stagger, substantial arrival delays would have been normal for those weather conditions, perhaps resulting in flight cancellations. TWA expressed verbal praise to the FAA for CRDA stagger due to their experiences and the dramatically reduced arrival delays on that day. A TWA representative verbally stated that 6 January was the first time that St. Louis had IFR conditions almost all day and the airline experienced no flight cancellations. Other user responses have been made in writing and can be found in appendix F.

On 28 January 1992, St. Louis ran CRDA for three arrival rushes. Weather conditions included a measured ceiling of between 700 and 900 feet and visibility was reported to be between 2 and 3 miles with snow and fog. Before CRDA, St. Louis would have set a 36 arrival rate for the above weather conditions and a National Program would have been enforced by Kansas City Center. With CRDA, St. Louis set an arrival rate of 48 aircraft per hour. During the four hours that day when CRDA stagger was operational 42, 40, 40 and 43 aircraft per hour respectively landed at St. Louis, an average of 41 aircraft per hour. This was the total arrival demand on St. Louis during this time and, again, there were no arrival delays. In addition, the following hour when the arrival rate was increased to 54, St. Louis was able to land 40 aircraft. Prior to CRDA stagger, there were usually not enough aircraft in the system following cessation of a National Program for St. Louis to land more than 36 aircraft. No departure delays were reported by the TMC during the periods CRDA stagger was operational.

On 24 February 1992, St. Louis ran CRDA stagger for six consecutive arrival rushes. St. Louis had previously gotten approval to proceed to the next weather step-down. The measured ceiling that day ranged from 2600 to 7000 feet, but of significance visibility ranged

On 24 February 1992, St. Louis ran CRDA stagger for six consecutive arrival rushes. St. Louis had previously gotten approval to proceed to the next weather step-down. The measured ceiling that day ranged from 2600 to 7000 feet, but of significance visibility ranged from only 1 1/4 to 1 3/4 miles in both rain and fog. Prior to the implementation of CRDA stagger, St. Louis would have set an arrival rate of 36 and the Center would have put a National Program into effect. With CRDA stagger, the St. Louis TMC set an arrival rate of 45 for the first half hour of operations, and a rate of 48 for the remainder of the day. Over the ten hours when CRDA stagger was in operation, St. Louis reported actual arrivals per hour of 36, 45, 40, 39, 36, 42, 31, 49, 36, and 54 aircraft; an average of 41 aircraft per hour. For the day, St. Louis experienced an increase in throughput of at least 48 aircraft. 24 February was the first experience St. Louis had running with visibility low enough that the tower controller did not have visual contact with the aircraft at the threshold. Departure delays of up to 15 minutes were reported by the TMC at several times during the day.

5.4.3.4 Impact of Staggering on Departure Operations

In order to evaluate the impact of staggering operations on departures, the TMC logs and Tower Monitor logs for the periods when CRDA stagger was run were analyzed. In addition, informal questionnaires kept by the controllers in the tower and TRACON during stagger operations were consulted. It was concluded that as long as the tower controller had visual contact with the 30R arrival at the time that it crossed the runway threshold, departur delays during CRDA stagger operations were not a significant problem. Although more data needs to be collected at this point, it appears from the one experience during poor visibility (i.e., 24 February) that if there is substantial departure demand during the operation of CRDA stagger there will be departure delays in poor visibility conditions.

On 24 February 1992, while CRDA stagger was operational, St. Louis was able to depart 25, 40, 35, 41, 41, 35, 33, 39, 45, and 29 aircraft per hour, respectively. Still, St. Louis reported departure delays of up to 15 minutes. Since the final step-down requires stagger operations where visibility falls below 1 mile, the completion of Phase IV may provide sufficient data to determine the extent of the departure problem during periods of low visibility. Although no recommendations are being made at this time, if the departure problem does indeed turn out to be significant, the following operational solutions should be considered. The most drastic solution would be to restrict stagger operations to weather conditions where visual separation can be utilized. Another approach would be to restrict stagger operations during low visibility only when departure demand warrants discontinuing use of CRDA. Finally, the site may want to consider using slightly less optimal stagger separation for arrivals (e.g., a 2 1/2 or 3 mile stagger) in order to open up a greater number of departure slots.

5.4.3.5 Assessment of the Need for a CRDA Monitor Controller

The last objective of Phase IV was to assess the need for an additional staff position, monitor controller, to provide an extra measure of safety during stagger operations. Based on the

the position is no longer needed, or that the position should only be staffed during specific operational conditions.

The informal evaluation at St. Louis consisted of logging the actions taken by the LC-3 monitor, if any, and determining whether the LC-N position could have just as easily handled the additional workload. Additionally, independent observers in the tower during CRDA stagger operations, the controllers working the two positions in the tower, and the tower supervisors were interviewed. Based on the informal evaluation, St. Louis has decided that for the weather conditions under which they have currently operated CRDA stagger and the level of experience that they have gained with the aid that the monitor position should not be mandated. As St. Louis gains more experience with CRDA stagger operations during low visibility, the need for the monitor controller position will continue to be assessed through the completion of Phase IV, and after the official completion of Phase IV. Currently, St. Louis plans to determine whether an LC-3 monitor is needed on a case-by-case basis, and expects to use the monitor on an exception basis, rather than routinely in IFR conditions. For example, when unusual weather conditions such as extremely adverse winds or heavy icing occur which require more controller attention, St. Louis may still use the extra controller in the tower.

5.4.4 Results of the ORR

The Operational Readiness Review for Phase IV has not yet been held due to the fact that St. Louis has not handled enough arrivals to runway 24 at the final weather step-down level to complete Phase IV.

SECTION 6

SUMMARY AND CONCLUSIONS

This section presents a summary of the CRDA evaluation at St. Louis and presents conclusions drawn as a result of the operational evaluation.

6.1 SUMMARY

During the period December 1990 through the publication of this report, a four-phased operational demonstration and evaluation of CRDA was conducted at Lambert-St. Louis International Airport. The intent of the evaluation was to determine the operational benefits of using CRDA during VFR conditions, and as a visual aid in support of DCIA during IFR conditions, at St. Louis, and to assess the operational suitability of the CRDA as a step toward possible national implementation of the aid at selected airports which have converging or intersecting runway configurations.

After controller training on the two CRDA modes of operation to be used at St. Louis -- tieing and staggering -- the CRDA was evaluated in a live operational environment. The evaluation was oriented toward answering a number of specific operational questions in the following three areas:

- From the viewpoint of airport operations, (a) does the aid provide an operational benefit to the facility?; (b) how can the aid best be used to facilitate St. Louis operations?; and (c) what can be learned at St. Louis to support the implementation of the aid at other facilities during national implementation?

- From the viewpoint of the controller (TRACON and tower controllers), does the aid need to be modified prior to national implementation to improve its utility in an operational environment? If so, how?

- From the viewpoint of IFR procedures to be used with the aid, do the proposed IFR procedures assure that an adequate margin of safety is provided when the aid is used to conduct staggered, converging approaches in IFR?

Conclusions relevant to each of these areas are presented below for both the tieing and staggering modes of CRDA operation.

6.2 CONCLUSIONS

6.2.1 CRDA-Assisted Tieing Operations

6.2.1.1 Airport Operations Perspective

From the point of view of airport operations, the evaluation showed that the use of the CRDA does, in fact, provide the benefit of additional departure slots on runway 30R, while allowing triple runway arrivals to runways 24, 30R and 30L. To achieve this, the originally defined ghosting region for tieing was widened during the tieing evaluation phase, a simple procedure requiring modification of adaptation parameters. Further, given that the weather conditions are such that use of the runway 30's/24 configuration is appropriate, and that the ceiling is at least 800 feet and the visibility at least 2 miles, St. Louis has identified no conditions which preclude the use of tieing; for example, no range of wind conditions has been identified which is considered so adverse as to preclude the use of tieing.

Guidance material on CRDA-assisted tieing, based on lessons learned during the St. Louis evaluation, was developed to assist in the national implementation of CRDA. Such material has been developed in the following areas, and is presented in appendix G:

- Preparing for the operational use of CRDA
- CRDA training
- Transitioning into the operational use of CRDA
- CRDA operational use

6.2.1.2 Controllers' Perspective

From the perspective of the tower and TRACON controllers, the evaluation showed that the controllers could use the CRDA to achieve accurate ties on a sustained basis. Further, the only CHI modifications identified during the evaluation were those which are already being provided in the national version of CRDA (i.e., in ARTS IIIA, Version A3.05). Several recommendations were made to St. Louis related to how to improve the use of CRDA-assisted tieing at St. Louis, but these recommendations were in the area of suggested procedural modifications, and were therefore unrelated to the CRDA software program itself.

Additional controller workload for the runway 24 final approach controller was reported, but this is to be expected if the benefits of increased arrival and departure throughput are to be realized by the facility.

6.2.2 CRDA-Assisted Staggering Operations using the DCIA Procedure

6.2.2.1 Airport Operations Perspective

The operational evaluation of the DCIA procedure, assisted by the CRDA staggering application, has clearly shown that using CRDA-assisted staggering to support DCIAs provides an operational benefit to the facility by increasing the arrival throughput during IFR conditions. During pre-DCIA operations, the aircraft acceptance rate normally given to the Kansas City Center by the St. Louis TRACON was 36 aircraft per hour during IFR conditions. With DCIA and CRDA staggering, the rate given to the Center during IFR periods normally ranged between 42 and 48 aircraft per hour, depending on such factors as the visibility and anticipated departure demand. Analysis of CDR data further demonstrated that St. Louis did, in fact, routinely land more than 36 aircraft per hour using CRDA during such periods when there was sufficient arrival demand.

At the time of issuance of this report, the Central Region had initiated the process of increasing the Engineered Performance Standards (EPS) for St. Louis from 36 to 48 aircraft per hour for the 24/30 R,L configuration when St. Louis is running DCIA and conditions exceed an 800 foot ceiling and 2 miles visibility, and from 36 to 42 aircraft per hour down to CAT I weather minima. Although the EPS has not yet been officially changed, the Air Traffic Control System Command Center (formerly Central Flow Control) will accept these higher rates if requested by St. Louis when DCIA and CRDA are operational. The EPS is the acceptance rate number used in implementing national-level air traffic flow restrictions in poor weather conditions, or for other reasons affecting air traffic flow in large portions of the country.

In the area of airport operations, the St. Louis evaluation has also resulted in the conclusion that those facilities planning to use CRDA-assisted staggering should consider the use of a monitor position during stagger operations until sufficient experience is acquired with the aid that the facility feels either that the position is no longer needed, or that the position should only be staffed during specific operational conditions.

The last evaluation area related to airport operations was the impact of staggering operations on departures during combined arrival/departure rushes. It was concluded that as long as the tower controller had visual contact with the 30R arrival when it crossed the threshold, departure delays during CRDA stagger operations were not a significant problem at St. Louis. Although more data needs to be collected at this point, it appears from one experience during poor visibility (i.e., 24 February) that if there is substantial departure demand during CRDA-assisted stagger operations, there will be departure delays at St. Louis if visibility conditions are poor. The impact on departure operations is, however, dependent on site specifics (for example, distance from the tower to the threshold of the arrival runways); therefore, each site planning to use CRDA for staggering will need to evaluate the impact on departure operations, if any, and to formulate the best operational strategy for dealing with this potential problem area.

As in the case of CRDA tieing, guidance material for the national implementation of CRDA stagger was developed in the areas of preparing for operational use, training, transitioning into operations, and operational use. This material is contained in appendix G.

6.2.2.2 Controllers' Perspective

From the perspective of the TRACON and tower controllers, the evaluation showed that the controllers were able to consistently meet stagger separation requirements. Regarding the CRDA CHI for stagger operations, the general conclusion is that no modifications are required to the CRDA CHI interface for the St. Louis version of CRDA, and no modifications to the specified CRDA CHI are required for ARTS IIIA, version A3.05 (i.e., the national version of CRDA). Based on the St. Louis evaluation several recommendations were made that were related to suggested training or procedural modifications to either improve the use of CRDA during stagger operations at St. Louis or to aid in the national implementation of CRDA, but these recommendations were unrelated to the CRDA software program itself.

While CRDA-assisted staggering did not significantly increase workload for the TRACON controllers, tower controllers did notice a workload increase, as compared to their workload if single stream arrival operations were being conducted to runways 30R and 30L. However, this is to be expected if the benefit of an arrival throughput increase in IFR conditions is to be realized by the facility. It is expected that the difference in workload for tower controllers will diminish as more experience is gained with CRDA staggering operations by both the TRACON and tower controllers.

6.2.2.3 IFR Procedures Perspective

The last area of evaluation related to CRDA-assisted staggering was an assessment of the proposed IFR procedures to assure that an adequate margin of safety is provided when the aid is used to conduct staggered, converging approaches in IFR. Since there was no occurrence of consecutive missed approaches during actual IFR stagger operations with the aid, conclusions in this area need to rely on the extensive simulation analysis described in section 5.3.4.1 and the results of the live flight demonstration described in section 5.3.4.2. The general conclusion is that the 2 nmi/5 nmi rule applied at St. Louis, with the several restrictions contained in the St. Louis waiver, does provide the required margin of safety for stagger operations at St. Louis.

SECTION 7

RECOMMENDATIONS

7.1 GENERAL

Two major recommendations regarding the national implementation of CRDA can be derived from the operational evaluation of CRDA at St. Louis:

- Nothing was discovered about CRDA functionality or suitability for operational use which would preclude the national implementation of CRDA at other airports which have converging or intersecting runways. It is therefore recommended that the planned national implementation of CRDA, using the functionality of ARTS IIIA, Version A3.05, be continued. Further, based upon formal and informal favorable comments received from various aviation user organizations during the St. Louis evaluation of CRDA, the national implementation of CRDA should take place as expeditiously as possible.

- As part of the activity of nationally implementing CRDA, it is recommended that the guidance material for national implementation, presented as appendix G of this report, be made available to all sites that are considering the implementation of CRDA.

7.2 SPECIFIC

Specific recommendations which were presented to St. Louis to improve CRDA-assisted tieing operations are summarized in section 5.2.3, and in sections B.1.4 and B.2.4 of appendix B. Specific recommendations to St. Louis related to CRDA-assisted stagger operations are summarized in sections 5.4.3.1, 5.4.3.2, and 5.4.3.4, and in sections E.1.4 and E.2.4 of appendix E. Detailed recommendations with respect to the national implementation of CRDA are presented in appendix G as guidance material to those sites at which CRDA is to be implemented.

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APPENDIX A

STAGGERED APPROACHES TO CONVERGING RUNWAYS[7]

This appendix provides a description of the problem associated with conducting staggered approaches to converging runways and the CRDA concept for addressing the problem.

Description of the Problem

If a specific time or distance relationship is not required to be maintained between aircraft arriving on two converging streams, the approaches may be called independent or simultaneous. Figure A-1 is an example of such approaches. Figure A-2, on the other hand, is an example of staggered or "dependent" converging approaches. A distance relationship is required and maintained such that aircraft do not arrive at some point of concern (e.g., the missed approach point) simultaneously. The possibility of a collision during a simultaneous missed approach to both runways is the most significant safety issue in converging runway approaches. The generation of wake vortices by aircraft on such approaches also creates an important hazard. Staggering aircraft solves these issues by insuring that aircraft will not arrive at the selected point of concern simultaneously.

Simultaneous, or independent approaches to converging or intersecting runways are conducted routinely at many major airports under VMC, i.e., in weather conditions when the ceiling and visibility are greater than 1,000 feet and 3 miles, respectively. At certain airports they are conducted even in marginal IMC, e.g., when the ceiling and visibility are about 700 feet and 2 miles. Whether the converging stream is discontinued when conditions drop below basic VFR conditions, or below the marginal IFR conditions, the eventual loss of a converging stream causes a significant loss of airport capacity. For example, the arrival capacity for Lambert-St. Louis International Airport is reduced from about 100 or more arrivals per hour in VMC to less than 40 in IMC.

The difficulty with staggered converging approaches is that it is not easy for controllers to stagger aircraft precisely, especially on a sustained basis. It is difficult to estimate the distance, relative to a common reference point, between two or more aircraft on converging approaches, even though some perceptual clues do exist, such as one-mile dashes on the extended runway centerlines. If precise staggering is required, the task becomes even more difficult. Precise staggering, e.g., 2 nmi, would be required to realize the full capacity benefits of staggered converging approaches. Staggering also requires coordination between controllers, which adds to the complexity of the task. Finally, controller experience is also a relevant factor in that the task is more difficult for an inexperienced controller.

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7 The material in this appendix is partially extracted from Reference 1.

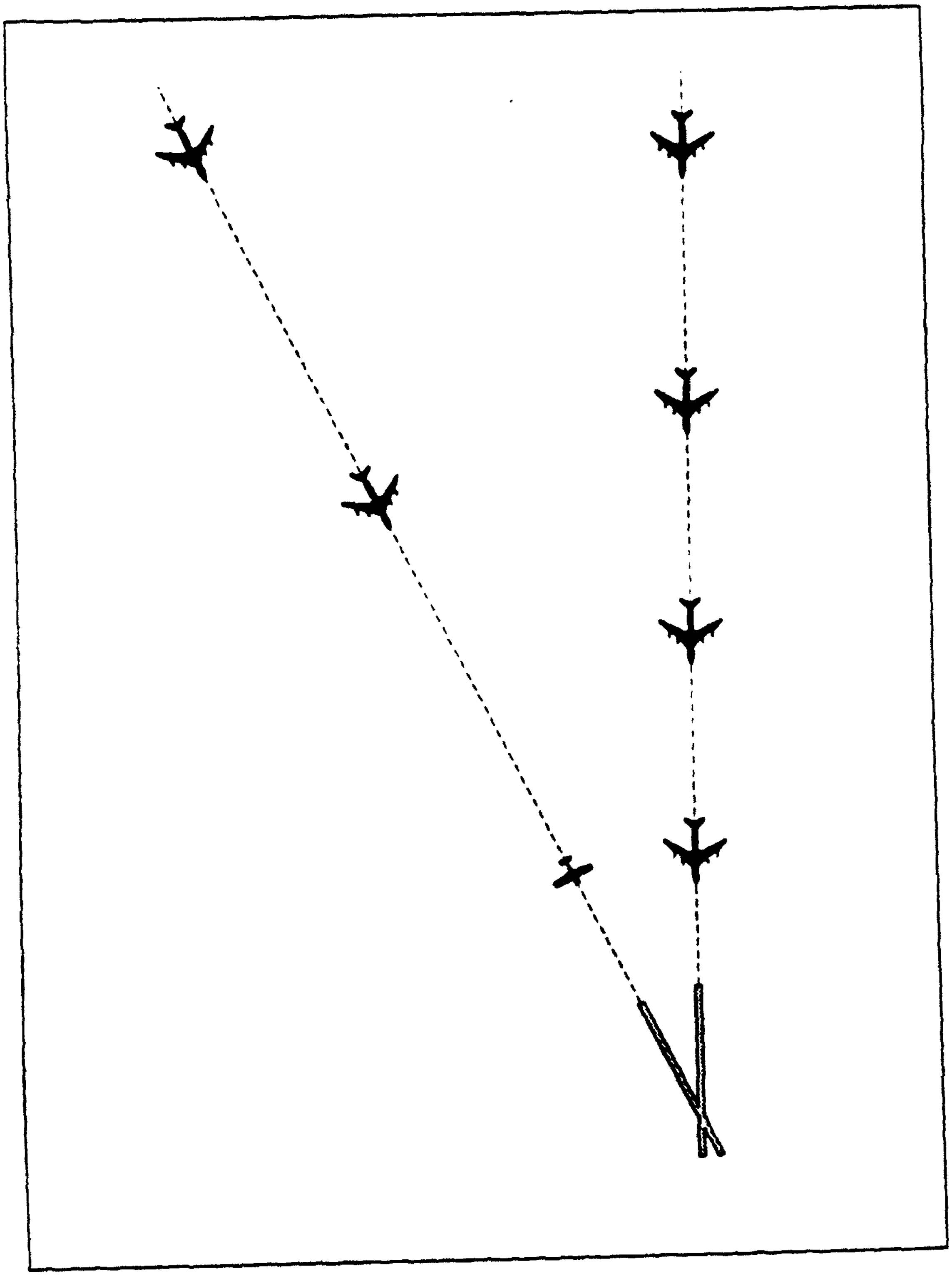

Figure A-1. independent Converging Approaches

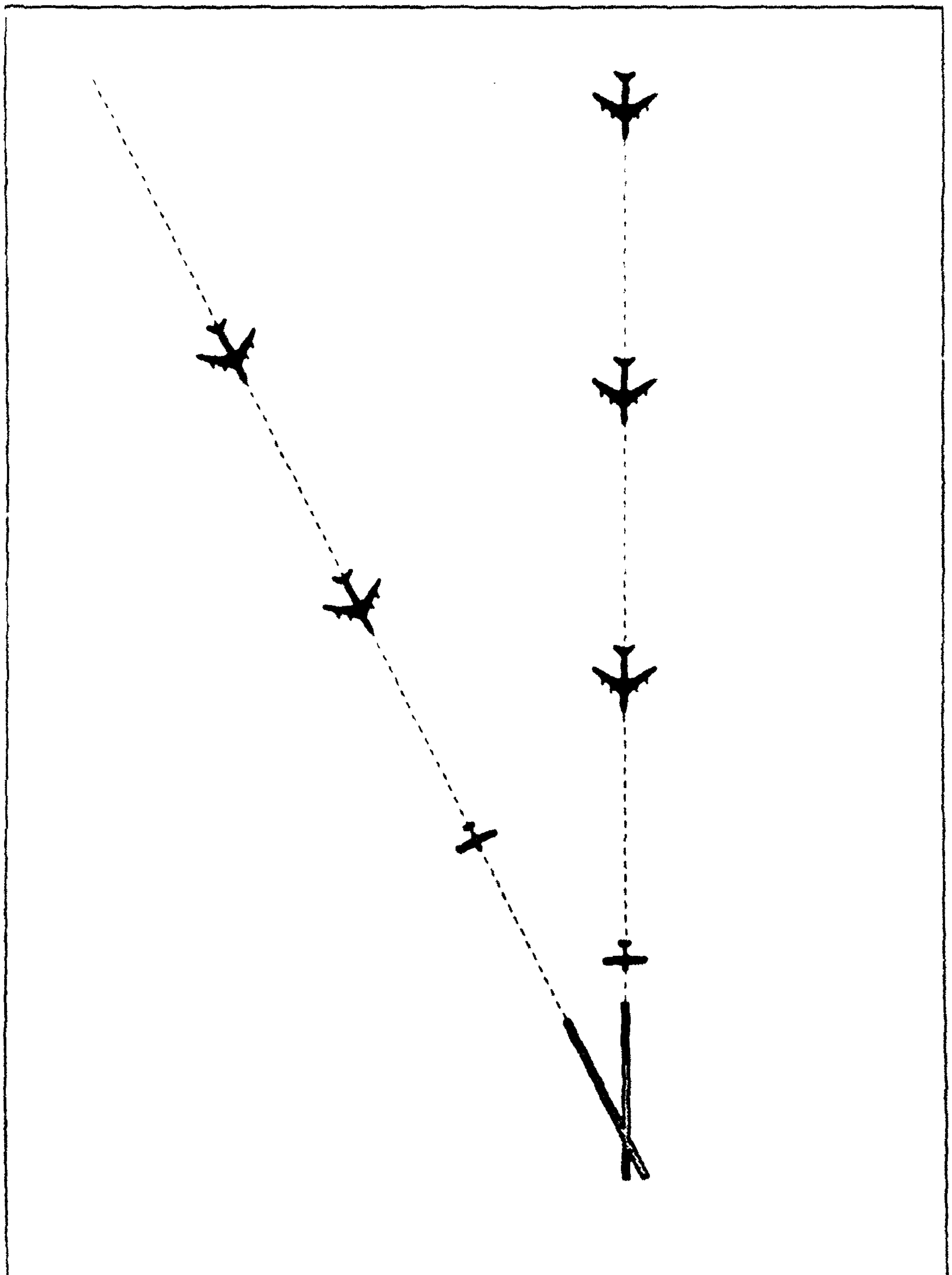

Figure A-2. Staggered Converging Approaches

The above discussion concerns only arrivals and the staggering of arrivals to maintain some desired capacity level. At some airports with certain runway configurations, i.e., Lambert-St. Louis, another problem exists during periods of high departure rates since the departures must be coordinated with the arrival streams. To do this efficiently when two arrival aircraft are executing converging approaches, controllers attempt to have both arriving aircraft cross their respective thresholds simultaneously. This operation is termed "tieing". Again, precise tieing is a more difficult task to perform without an automation aid.

The CRDA

The basic function of the controller aid, given two or more aircraft on converging approaches, is to create on an opposing approach a display of virtual images or "ghosts" of the real aircraft at the same distance from the runway threshold, or intersection, as the real aircraft on its actual approach path. This enables the controller to see precisely the distance between two real aircraft on converging approaches by observing the distance between one of the real aircraft and the "ghost" of the other aircraft on one of the approaches. Figure A-3 illustrates this concept. Whether the runway threshold or the intersection of the two runways is the reference point is determined by the algorithm based on the type of operation in use. If a tieing operation has been selected, the runway threshold is the reference point; if stagger operations are in use, the runway intersection is the reference point.

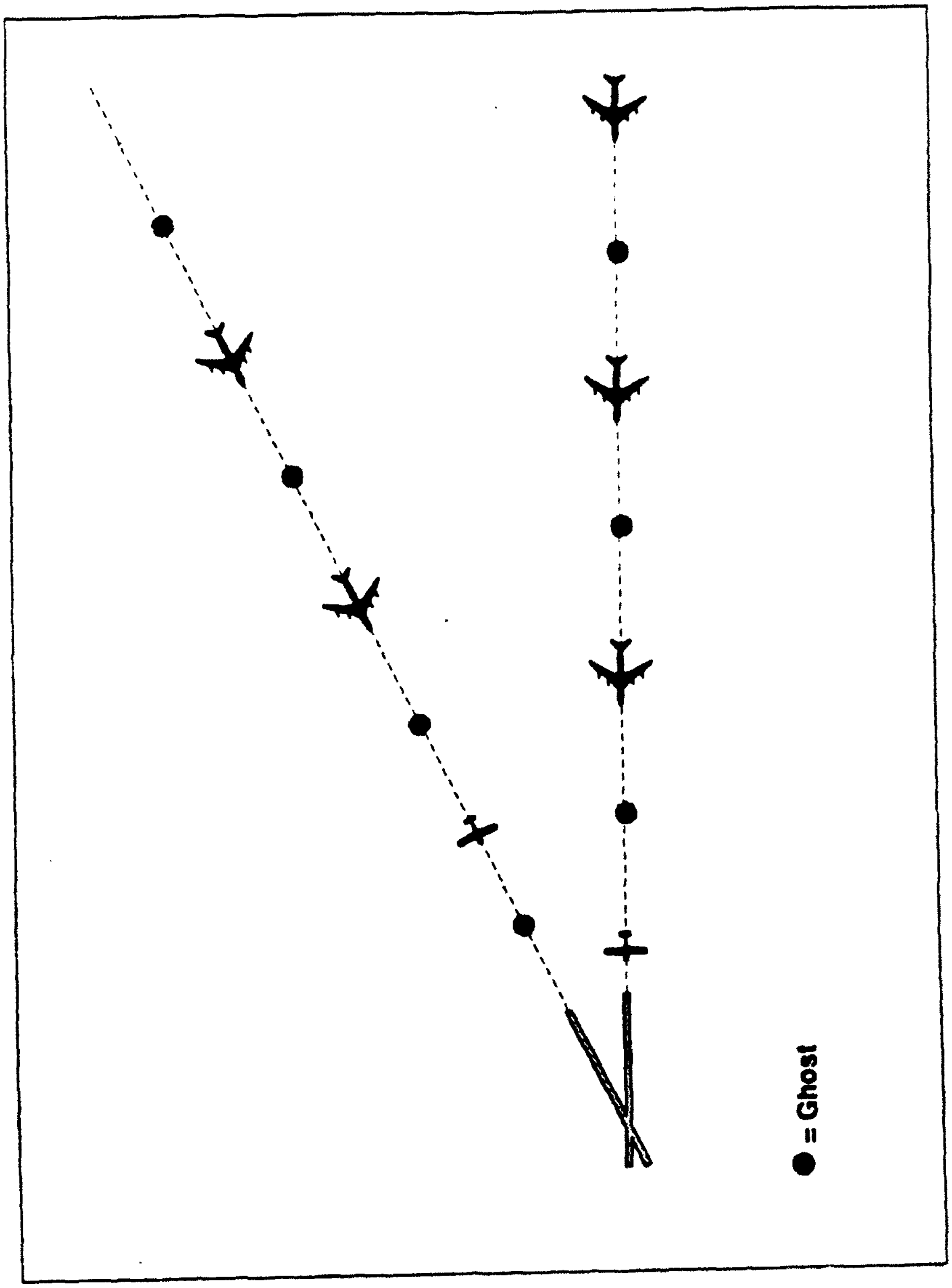

Figure A-3. Staggered Converging Approaches with Ghosting Generation

APPENDIX B

DETAILED RESULTS OF THE TIEING CONTROLLER QUESTIONNAIRES

Questionnaires regarding tieing operations with the CRDA were administered to TRACON and tower controllers who had experience with CRDA during the week of 4 - 8 March 1991. Representatives from the St. Louis Plans and Procedures Staff and MITRE attended the regularly scheduled controller team meetings for the purposes of handing out the questionnaires, explaining the intent of the questionnaires, and answering any questions pertaining to the questionnaire items. Because of limited controller exposure to the aid during bona fide traffic periods when tieing would be most appropriately used, the controllers were asked to respond taking that factor into account.

The formal evaluation via the questionnaires confirmed several findings which had surfaced during the informal day-to-day evaluation at St. Louis. The questionnaire responses also revealed findings in new areas, not previously identified. The questionnaire results are presented in this appendix. It should be noted that some controllers expressed concern regarding their ability to provide reliable feedback via the questionnaires, having had only limited exposure with CRDA during live operations.

B.1 RESULTS OF TRACON QUESTIONNAIRE

Of the 30 controllers who had used CRDA tieing during the evaluation period, 26 were available during the questionnaire exercise, and all 26 responded to the questionnaire. In addition, responses were received from 5 TRACON supervisors and 1 TMC. On the average, the respondents had approximately 5 years FPL experience at St. Louis. The respondents had limited tieing experience using CRDA, with 12 controllers indicating 2 - 10 hours of use and 14 controllers indicating less than 2 hours exposure. None of the controllers had greater than 10 hours of tieing experience when the questionnaire was administered.

The questionnaires were filled out independently by each respondent, without discussion between respondents during the process. The intent was to obtain the independent opinion of each respondent, without the possible biases which could result if a discussion environment were allowed to ensue, with perhaps several respondents dominating the discussion and possibly influencing the nature of the individual questionnaire responses.

B.1.1 Consensus Areas

After analyzing the questionnaire responses, it was clear that a consensus was reached on many of the areas addressed by the questionnaire. Those areas on which all or a sizable majority of the controllers agreed are described below:

- The respondents unanimously indicated that the data block associated with the ghost target should not be changed or augmented (i.e., the controllers were satisfied with the existing data block).

- Ninety-Four percent of the respondents had no difficulty in distinguishing between the ghost targets and those of actual aircraft. One of the two respondents who expressed some difficulty also indicated that he was just getting used to the CRDA aid, and that he expected no problem after awhile.

- The respondents reported very little use of the option available to suppress the display of ground speed in the data block.

- The respondents unanimously indicated that the manner in which ground speed was displayed in the data block of the ghost target was operationally acceptable. I.e., they felt that there was no confusion between the display of altitude for the actual aircraft and the display of ground speed for the ghost targets.

- Ninety-Four percent of the respondents either did not feel that the ghost data blocks resulted in an unacceptable level of clutter on the display, or they felt that any increase in clutter was insignificant compared to the benefit provided by CRDA.

- Sixty-Seven percent of the respondents indicated a need to widen and heighten the ghosting region. The controllers wanted to see the ghosts earlier in order get the traffic streams established as efficiently as possible.

B.1.2 Non-Consensus Areas

The respondents did not agree on several items addressed by the questionnaire. In addition to individual controller preferences, this lack of consensus might have been due to their limited experience with CRDA and perhaps the specific conditions that existed at the times CRDA tieing was used. The areas where the respondents did not reach a consensus of opinion are identified below:

- The respondents were divided over whether CRDA was "essential", "very helpful", or not helpful to them to achieve accurate ties over a sustained period of time. However, none of the respondents chose a response which indicated that CRDA adversely affected his/her ability to perform the tieing task. (In answering this question, the controllers were asked to assume that they were required to tie arrivals to runway 30R with those aircraft coming into runway 24.)

- The respondents did not agree as to whether using CRDA for tieing affected their ability to perform their other controller tasks. Nearly 60 percent (18 of 31) of the respondents indicated that the CRDA either did not affect the performance of their other tasks, or that CRDA permitted easier performance of other controller tasks.

Most of the respondents who reported that CRDA did interfere with those other tasks felt it did so only occasionally, as opposed to often. Due to their limited exposure to CRDA, this discrepancy was likely due to specific conditions that existed during the period that CRDA was run. For example, those runway 24 controllers with significant VFR traffic at one or more satellite airports under their control were more likely to report interference during a tieing period. The runway 24 controller in this case has the dual responsibility of handling satellite airport traffic, as well as performing tieing of Lambert runway 24 arrivals with arrivals to runway 30R.

- There was disagreement over how significantly wind conditions affected controller ability to consistently achieve satisfactory ties. Of the 24 respondents who had had experience using CRDA tieing in adverse wind conditions, 11 (~ 46 percent) reported that wind was sometimes a factor, but after a short time it was easy for them to compensate for the wind. Ten other respondents felt that certain wind speeds and directions could make it difficult to achieve satisfactory ties, although, with work, tieing could be accomplished. (Head winds were mentioned most frequently as being difficult to accommodate, with a strong head wind to runway 30R being especially difficult.)

B.1.3 Other Opinions Expressed

In addition to the specific questions to which the controllers were asked to respond, several concerns and opinions were expressed by the TRACON controllers. Each of the concerns and opinions listed below was expressed by several questionnaire respondents:

- Some runway 24 controllers expressed the opinion that it was difficult for them to satisfactorily tie with the aircraft arriving to runway 30R when the 30R final was not fully established or when 30R spacing between aircraft was poor. The controllers felt that the 30R final should be established out to at least 20 miles. (This concern may have arisen due to the fact that operational evaluation of the tieing function was run at less than optimal traffic levels, due to the need to have the controllers acquire some experience with CRDA.)

- Several controllers felt that the ghost target should be positioned such that the actual runway 24 aircraft could be superimposed on top of the ghost, rather than be placed 1/2 mile behind it.

- Since the runway 30R ghost targets only appear to the runway 24 controller if they have been scratchpadded (i.e., the runway assignment of 30R has been entered into the scratchpad area of the data block by the controller), several runway 24 controllers mentioned that late scratchpadding by the 30R controller made it more difficult for them to tie aircraft. This concern is expected to be alleviated as the controllers gain more experience with CRDA.

B.1.4 Recommendations

Based on MITRE's analysis of the TRACON questionnaire responses, it was recommended that St. Louis promptly widen and heighten the ghosting region used for tieing. Before changing the region for actual operations, however, it was decided that St. Louis should evaluate the region via ETG testing with several scenarios to determine the desired boundaries.

Furthermore, when traffic demand and weather conditions permit more sustained use of tieing operations, it was recommended that St. Louis:

- Emphasize the need for the 30R final to be established out to 20 miles, for the 30R controller to maintain consistent spacing, and for the 30R controller to enter timely assigned runway information into the scratchpad,

- Monitor the workload of the 24 final controller and evaluate whether there is a need to split that position,

- Monitor the display to determine whether clutter begins to become a problem as traffic increases, and

- Further evaluate the effect of wind conditions on tieing. This evaluation should include determining whether specific wind conditions should preclude the use of tieing operations, and facilitating information exchanges between controllers on the best techniques employed to deal with difficult wind conditions.

B.2 RESULTS OF TOWER QUESTIONNAIRE

Of the 18 local controllers at St. Louis at the time of the questionnaire exercise, 12 indicated that they had experience with CRDA tieing operations, and all 12 responded to the questionnaire. In addition, 3 tower supervisors responded. The tower questionnaires were administered at regularly-scheduled tower team meetings in a manner similar to the TRACON questionnaire. Respondents had an average FPL experience of 3 years at St. Louis. As with the TRACON controllers, the tower controllers had limited experience with the CRDA tieing function when the questionnaire was administered.

B.2.1 Consensus Areas

The tower respondents reached a consensus on most of the areas covered on the questionnaire. All or a large majority of the controllers agreed on the items listed below:

- Every respondent agreed that there was a definite operational benefit, or a benefit in certain cases, to tieing using the CRDA program and generating ghost targets.

- Eighty-Seven percent of the respondents felt that their job was made "much easier" or "somewhat easier" with CRDA, given that St. Louis was required to tie 30R and 24 arrivals.

- Ten respondents (i.e., 67 percent) indicated that they occasionally had to intervene by using a speed or vector command in order to achieve a satisfactory tie. Two respondents indicated that they never had to intervene, and three responded that intervention was rare; but no respondent indicated that intervention was required "often".

- All but one of the respondents felt that the DBRITE displays presented the ghost target data adequately to support the local controller tasks during periods of tieing operations.

- Eighty percent of the respondents (i.e., 12 of 15) reported no difficulty in distinguishing between ghost targets and targets from actual aircraft. Of the remaining three, one respondent indicated difficulty "occasionally" and two indicated difficulty "very rarely".

B.2.2 Non-Consensus Areas

The tower controllers responding to the questionnaire did not agree on whether the coordination between the Tower and TRACON was adequate, both during the initiation and operation of CRDA. The tower controllers also did not agree on whether the 1/2 mile offset used to create departure slots on runway 30R was appropriate; 10 of the 15 respondents felt the 1/2 mile offset was appropriate, while the remaining 5 felt it was not.

B.2.3 Other Opinions Expressed

In addition to the specific questions to which the controllers were asked to respond, several concerns and opinions were expressed by the tower respondents. Several tower controllers expressed a desire to have the capability to control the direction of the leader lines on the DBRITE. Although this feature was not implemented for the operational evaluation version of CRDA at St. Louis, it is planned for the national implementation version in ARTS IIIA 3.05. Several respondents expressed the opinion that aircraft which land on runway 24 and cannot hold short of runway 30L cause a problem because a departure slot on runway 30L may be lost. While this is not a problem with the CRDA program, it pointed up the need for St. Louis to decide whether to limit those types of aircraft allowed to land on runway 24 during CRDA tieing operations.

B.2.4 Recommendations

Based on the analysis of the tower questionnaire responses, it was recommended that St. Louis develop more explicit tower/TRACON coordination procedures for using the CRDA tieing application. These coordination procedures include:

- Notification by the tower to the TRACON as to when tieing is needed and what spacing is required, and when tieing should be discontinued,
- Notification by the TRACON to the tower indicating the first aircraft to be tied, and advising that CRDA tieing has been activated, thus permitting tower personnel to know when to turn on the Quick Look function, and
- Feedback from the tower to the TRACON as to the accuracy of the ties, whether due to winds or other factors.

A final recommendation resulting from the formal evaluation was for St. Louis to re-evaluate the appropriateness of the 1/2 mile offset rule for placement of the runway 24 aircraft behind the runway 30R ghost target.

B.3 PHASE II TRACON QUESTIONNAIRE

The TRACON questionnaire used during Phase II of the CRDA evaluation is shown on the following pages.

B.4 PHASE II TOWER QUESTIONNAIRE

The tower questionnaire used during Phase II of the CRDA evaluation is shown on the following pages.

QUESTIONNAIRE ON TIEING OPERATIONS WITH THE CONVERGING RUNWAY DISPLAY AID (CRDA)

In all sections, please fill in the requested information, or check the answer which most closely matches your response. For Sections II and III, please use the last page of the questionnaire if you need more space to respond to any question.

SECTION I

GENERAL INFORMATION

1. Name: ______________________________

2. Date: ______________________

3. Years FPL: ________________

4. Length of time certified as an STL feeder, final approach, or low altitude controller: _______________

5. Approximate number of hours you have used CRDA for actual tieing operations as a final approach controller to Runway 24:

- ☐ (a) Less than 2 hours
- ☐ (b) 2-10 hours
- ☐ (c) More than 10 hours

SECTION II

GENERAL QUESTIONS ON USE OF THE CRDA IN TIEING OPERATIONS

1. Assuming that you are required to tie arrivals to Runways 24 and 30R, which of the following statements best applies:

☐ (a) Use of the CRDA is essential to providing consistent and accurate ties over a sustained period of time

☐ (b) The CRDA is very helpful in performing the tieing task; however, I believe I could perform the task on a sustained basis without it, but my workload would be increased

☐ (c) I believe I could perform the tieing task just as well without the CRDA, and my workload would be about the same

☐ (d) Use of the CRDA adversely affects my ability to perform the tieing task

☐ (e) Other:____

2. Do you believe that your overall opinion regarding the utility of the CRDA for conducting tieing operations has changed since you first used the aid in actual operations?

☐ (a) My opinion of the CRDA is considerably more favorable now than initially

☐ (b) My opinion of the CRDA is somewhat more favorable now than initially

☐ (c) My opinion now is basically the same as it was initially

☐ (d) My opinion of the CRDA is somewhat less favorable now than it was initially

☐ (e) My opinion of the CRDA is considerably less favorable now than initially

If your opinion has changed, what do you believe influenced the change?:____

3. We want to find the best ways to introduce the CRDA to other facilities. When you first began to use CRDA during actual tieing operations, what were your first reactions and general opinion about the operational utility of the aid?

☐ (a) Very useful

☐ (b) Useful

☐ (c) No firm opinion initially

☐ (d) Not useful, but also not harmful to performing my control functions

☐ (e) Not useful, and interfered with performing my control functions

☐ (f) Other:____

If your response was (e), please describe the problem(s) which you felt were introduced by the CRDA:____

4. What are the effects on your other controller tasks when using the CRDA to conduct tieing operations?

☐ (a) Use of the CRDA allows easier performance of my other controller tasks

☐ (b) Use of the CRDA does not affect the accomplishment of my other controller tasks

☐ (c) Use of the CRDA <u>occasionally interferes</u> with the performance of my other controller tasks

☐ (d) Use of the CRDA <u>often interferes</u> with the performance of my other controller tasks

If your response was (c) or (d), which of your controller tasks are adversely affected? ______________________________________

5. Do you find that wind conditions affect your ability to achieve satisfactory ties with the CRDA?

☐ (a) I have had <u>no opportunity</u> to use the CRDA for tie operations in adverse wind conditions

☐ (b) Wind conditions <u>do not affect</u> my ability to perform satisfactory tieing operations with the CRDA

☐ (c) Wind conditions are <u>sometimes a factor</u>, but after a short adjustment period I find that I <u>can easily accommodate wind conditions</u> with CRDA

☐ (d) Sometimes wind conditions are such that it is <u>difficult to achieve good ties</u> with CRDA, although I can do it

☐ (e) Sometimes I am <u>unable to achieve the required ties</u> with CRDA due to wind conditions

☐ (f) Other:______________________________________

If your response was (d) or (e), what wind conditions (direction and magnitude) make tieing difficult or unfeasible at all with tieing operations to Runways 24 and 30R?

____

6. Are there any other factors which prevent you from achieving consistent, accurate ties with the CRDA, or which make it difficult for you to do so (e.g., short turn-ons to 30R)? If so, please identify them:____

SECTION III

SPECIFIC QUESTIONS RELATED TO THE DISPLAY AND DATA ENTRY FEATURES OF THE CRDA

1. Is any additional information necessary in the ghost data block? (I.e., in addition to the ghost position symbol, leader, ground speed, and heavy jet indicator)

☐ (a) No

☐ (b) The following information is required: ____________________

____

☐ (c) The following information is desired, but not required: ________

____

If your response was (b) or (c), please indicate why you believe the additional information is required or desired: ____________________

____

2. Do you have difficulty in distinguishing ghost targets from actual aircraft?

☐ (a) Absolutely no difficulty in distinguishing between the two

☐ (b) I have difficulty in distinguishing between the two

  ☐ (i) Often

  ☐ (ii) Occasionally

  ☐ (iii) Very rarely

If (b) was selected, do you have any suggestion on how to better distinguish between ghost targets and actual aircraft?

____

3. Ghost targets are displayed when (1) the associated aircraft enters a predefined geographic area and (2) when the assigned runway has been entered into the scratchpad area. Are the ghost targets displayed at the right time?

- ☐ (a) Yes
- ☐ (b) Displayed too early
  - ☐ (i) Sometimes, but not often enough to be a nuisance
  - ☐ (ii) Often enough that I consider it to be a nuisance
- ☐ (c) Displayed too late
  - ☐ (i) Sometimes, but not often enough to adversely affect my control operation
  - ☐ (ii) Often enough that it adversely affects my control operation

4. The current system allows the individual controller to request or suppress the display of ground speed for all ghost targets (i.e., not on an individual ghost basis). Which of the following best describes your use of the ground speed display for ghost targets?

- ☐ (a) I always use the ground speed display
- ☐ (b) I sometimes suppress the ground speed display
- ☐ (c) I never use the ground speed display

If your response was (b), please identify the conditions when you typically suppress the display:____

5. Is the display of the ground speed in the ghost data block operationally acceptable? (I.e., is there any confusion since altitude is usually displayed in full or partial data blocks for real targets where ground speed is now displayed in ghost data blocks?)

☐ (a) Acceptable

☐ (b) Not acceptable

If your response was (b), do you have an alternative to suggest?

____

6. The display of ghost data blocks is new information presented on the ARTS display. To minimize display clutter, the ghost data blocks can be offset independently from the data blocks for actual aircraft. Which statement most accurately describes your opinion regarding display clutter?

☐ (a) The ghost data blocks <u>do not significantly contribute to display clutter</u>

☐ (b) The ghost data blocks <u>contribute to display clutter, but the overall assistance</u> provided by the CRDA during tieing operations <u>outweighs the disadvantage</u> presented by clutter

☐ (c) The additional clutter <u>significantly interferes</u> with my ability to use the CRDA during tieing operations

☐ (d) Other: ____

If your response was (b),(c) or (d), do you have any suggestions as to how to reduce the clutter, yet still display the ghost information?

____

____

7. In addition to any suggestions you may have made above, do you have any other suggestions or recommendations on how to improve the operational utility of the CRDA for tieing operations?

____

____

8. In your opinion, are there any operational problems associated with the use of the CRDA for tieing operations, beyond those addressed by the above questions? If so, what are they? ______________________________

____

____

CONTINUATION SHEET:

If you need more room to respond to any of the questions, please indicate the Section number (II or III) and the question number, and continue your response on this sheet.

TOWER QUESTIONNAIRE ON TIEING OPERATIONS WITH THE CONVERGING RUNWAY DISPLAY AID (CRDA)

In all sections, please fill in the requested information, or check the answer which most closely matches your response. For Sections II and III, please use the last page of the questionnaire if you need more space to respond to any question.

SECTION I

GENERAL INFORMATION

1. Name: ______________________________

2. Date: ________________________

3. Years FPL: _____________

4. Length of time certified as an STL local controller: _____________

5. Have you controlled traffic as a local controller when CRDA has been used for tieing operations?

☐ (a) Yes

☐ (b) No

SECTION II

GENERAL QUESTIONS ON THE USE OF THE CRDA IN TIEING OPERATIONS

1. The intent of the tieing operation is primarily to provide more opportunities for departures on 30R, while allowing the use of Runway 24 for arrivals. From your perspective, is the tieing operation meeting this operational objective?

- ☐ (a) There is a definite operational benefit to the tieing operation
- ☐ (b) There appears to be some benefit in certain cases
- ☐ (c) I see no particular benefit from the tieing operation as compared to before the use of CRDA, but there also appears to be no adverse impact
- ☐ (d) Tieing with CRDA is having an adverse impact on operations

If your response was (d), what is the adverse impact? ____________________

____

____

2. In your opinion, is the 1/2 mile offset approximately correct for creating departure slots on runway 30R?

- ☐ (a) Yes
- ☐ (b) No

If your response was (b), what offset would you recommend and why? ______

____

____

3. How often do you have to intervene by issuing a speed or vector command to achieve a satisfactory tie?

- ☐ (a) Never have needed to
- ☐ (b) Rarely
- ☐ (c) Occasionally
- ☐ (d) Often

4. What are your views regarding tower/TRACON coordination in initiating tieing operations with CRDA and during operations with CRDA?

- ☐ (a) The current coordination procedure appears adequate
- ☐ (b) Coordination between the tower and the TRACON is generally acceptable, but can sometimes be improved
- ☐ (c) The tower/TRACON coordination procedure needs to be improved

If your response was (b) or (c), how would you recommend that the coordination be improved? ______________________________

____

____

5. Assume that the facility is <u>required</u> to tie arrivals to runways 30R and 24. In this situation, is your job made easier because of the CRDA?

- ☐ (a) Much easier
- ☐ (b) Somewhat easier
- ☐ (c) About the same as without the CRDA
- ☐ (d) More difficult

If your response was (d), please explain: ______________________________

____

SECTION III

SPECIFIC QUESTIONS RELATED TO THE TOWER DISPLAY FEATURES OF THE CRDA

1. Do the DBRITE displays adequately present ghost target data to permit you to perform your controller tasks during tie operations?

☐ (a) Yes

☐ (b) No

If your response was (b), what recommendations would you make for improving the display of ghost target data on the DBRITES? ______________

____

____

2. Do you have difficulty in distinguishing ghost targets from actual aircraft?

☐ (a) Absolutely no difficulty in distinguishing between the two

☐ (b) I have difficulty in distinguishing between the two

  ☐ (i) Often

  ☐ (ii) Occasionally

  ☐ (iii) Very rarely

If (b) was selected, do you have any suggestion on how to better distinguish ghost targets and actual aircraft? ______________________

____

____

3. In addition to any suggestions you may have made above, do you have any other suggestions or recommendations on how to improve the operational utility of the CRDA for tieing operations in the tower?

____

____

____

4. In your opinion, are there any operational problems associated with the use of CRDA for tieing operations in the tower, beyond those addressed by the above questions? If so, what are they? ________________

____

____

CONTINUATION SHEET:

If you need more room to respond to any of the questions, please indicate the Section number (II or III) and the question number, and continue your response on this sheet.

APPENDIX C

ST. LOUIS AUTHORIZATION

Attached is the waiver memorandum from the Director, Air Traffic Rules and Procedure Service, ATP-1, authorizing the St. Louis Airport Air Traffic Control Tower to conduct dependent converging instrument approaches effective September 3, 1991 for a period of 2 years.

APPENDIX C

ST. LOUIS AUTHORIZATION

Memorandum

U.S. Department of Transportation

Federal Aviation Administration

Subject: INFORMATION: Request for Waiver to Order 7110.65F, Paragraph 5-72, and paragraph 5-114 for St. Louis, MO (STL) ATCT

Date: SEP 3 1991

From: Director, Air Traffic Rules and Procedures Service, ATP-1

Reply to Attn. of:

To: Manager, Air Traffic Division, ACE-500

The attached waiver permits the STL ATCT to conduct dependent converging instrument approaches in accordance with the prescribed procedures contained in Waiver 91-25-120.

The waiver/authorization is effective September 3, 1991 and is valid for 2 years. Request for renewal of this waiver should be made at least 120 days prior to its expiration date of September 2, 1993.

L. Lane Speck

Attachment

Waiver 91-25-120
Date: 9/3/91

FEDERAL AVIATION ADMINISTRATION
AIR TRAFFIC DIRECTIVES
WAIVER/AUTHORIZATION

ISSUED TO:

Manager, Air Traffic Division, ACE-500, for St. Louis Airport (STL) ATCT.

AFFECTED DIRECTIVE(S):

Order 7110.65, Paragraph 5-72.
Order 7110.65, Paragraph 5-114.

OPERATIONS AUTHORIZED:

This waiver authorizes the STL ATCT:

1. To conduct dependent converging instrument approaches (DCIA) during instrument flight rules conditions, using the converging runway display aid (CRDA), to Runways 24 and 30R.

2. To utilize a minimum of 2NM lateral separation between aircraft established on converging localizers.

3. To utilize less than 2NM separation between a missed approach aircraft on either Runway 30R or Runway 24 and an arrival on the converging runway.

SPECIAL PROVISIONS, CONDITIONS, LIMITATIONS:

The following items are required for conducting DCIA:

1. 2NM or more intrail spacing between a leading non-heavy aircraft and a trailing aircraft on approach to the converging runway when the leading aircraft is at the landing threshold.

2. 5NM or more intrail spacing between a leading heavy aircraft and a trailing aircraft on approach to the converging runway when the leading aircraft is at the landing threshold.

3. Operating control tower.

4. Operating airport surveillance radar (ASR) and CRDA.

5. Nonintersecting final approach courses.

6. A facility directive specifying, as a minimum:

(a) Each applicable runway configuration.

(b) Coordination requirements.

(c) Weather minima applicable to each configuration if different from published minima.

7. Direct communications capability between the final approach control position for each converging runway and the associated local control position.

8. Only straight-in approaches will be made.

9. Navigational aids and air traffic control frequencies shall be operating properly. Minimum requirements are a localizer operating on each runway.

10. Aircraft shall be informed on initial contact or as soon as possible thereafter that dependent converging approaches are in use. This information may be provided through the automated terminal information service (ATIS).

11. All single engine or non turbo twin engine aircraft shall utilize Runway 24.

12. All heavy aircraft shall utilize Runway 30R.

13. Aircraft with final approach speeds greater than 150 knots are not authorized to participate in the DCIA procedure.

REPORTING REQUIREMENTS:

1. Record any occurrence of consecutive missed approaches on the Daily Record of Facility Operation, Form 7230.4, and submit a brief summary to the Air Traffic Procedures Division, ATP-100, through ACE-500, within 72 hours. Include aircraft identification, type, weather, reason for each of the missed approaches, and any other pertinent data. Consecutive missed approaches are defined as two missed approaches by aircraft on two converging approaches occurring within 2 minutes of each other.

2. Notify ATP-100 within 24 hours of any operational error/deviation, pilot deviation, TCAS resolution advisory, or near mid-air collision report involving the CRDA.

3. Provide ATP-100 with a monthly report on the number of aircraft that utilize CRDA under the provisions of this waiver.

This waiver is effective September 3, 1991 and is valid for 2 years. A request for renewal of this waiver should be made at least 120 days prior to the expiration date.

for Theodore H Davies

L. Lane Speck
Director, Air Traffic
Rules and Procedures Service, ATP-1

APPENDIX D

MISSED APPROACH FLIGHT DEMONSTRATION PLAN

This appendix contains the flight demonstration plan which was developed by MITRE. It was used for the planning, conduct, and subsequent data analysis of the flight demonstration.

D.1 PURPOSE

The purpose of this demonstration is two-fold. The first is to provide a real life confirmation that separation will be provided in the event of consecutive missed approaches. Second, the results will be used to confirm MITRE's model of consecutive missed approaches.

D.2 SCOPE

There will be two aircraft whose time and pilots will be provided by a corporation. The two aircraft will be a Falcon-90 (jet) and a Beech King Air (twin turbo). There will be four scenarios run where both aircraft will descend to their respective missed approach points and then miss the approach, flying the published missed approach procedure. Observers in the TRACON, tower, and on the two aircraft will record certain specified data which will be reduced after the fact by MITRE.

D.3 SCENARIOS

The scenarios will be characterized by a speed of 170 kts (KIAS) to the outer marker followed by a deceleration to a final approach speed. This will be followed by a miss at the missed approach point followed by an acceleration to a predetermined "miss speed". The climb profile is not as important as achieving the speed schedule. The pilots will fly straight out until they reach the end of the runway after which they may be vectored by the controller.

There will be a practice run which will serve two purposes. 1) It will allow the pilots and the observers to become familiar with the sequence of events and the required actions (e.g., recording data, announcing events over the radio, etc), and 2) it will provide extra altitude separation over the intersection to confirm the missed approach model's basic validity.

The following table summarizes the parameters for the four scenarios.

Scenario	Leader	Beech			Trailer	Falcon		
	AC Type	Runway	FAS	Miss Speed	AC Type	Runway	FAS	Miss Speed
0**	ATR42	30R	110	120	L1011	24	135	142
1	B767	30R	125	146	Merlin	24	140	143
2	Beech	30R	105	*	Falcon	24	130	*
3	ATR42	30R	110	120	L1011	24	135	142
4	ATR42	24	100	112	B727	30R	140	148

* The aircraft in this scenario will approach, miss, climb and accelerate as they would normally do.

** This is a practice scenario where the leading aircraft will miss at TBD feet and the trailer will miss at TBD feet.

The controllers will be instructed to provide 170 kts to outer marker and to insure that in Scenario 0 the ghost of the trailer is 2 nmi behind the leader when the leader is at its threshold. In Scenario 1 the ghost of the trailer is 5 nmi behind the leader when the leader is at its threshold. For Scenarios 2 through 4 the ghost of the trailer will be 2 nmi behind the leader when the leader is at its threshold.

D.4 DATA COLLECTION LOGISTICS

The data collection needs to capture the following data:

- The complete track history of the flights
- The time, position and speed of the aircraft at their respective missed approach points
- The time, position and speed of the trailing aircraft when the leader is at the intersection
- The time and speed when the trailing aircraft is at the intersection

To achieve the gathering of these data the following activities will take place:

- A CDR recording covering the time of interest will be copied to tape. MITRE will reduce the tape *[STL -> MITRE]*
- The facility voice recording with the time channel will be made available. MITRE will transcribe the events and time from the recording with the help of STL personnel *[STL -> MITRE]*

- Both aircraft will be on the same tower frequency *[STL]*

- A video recording of the maintenance scope will be made with the recorder "listening" to the tower frequency (this will record the events as well as the time) *[MITRE]*

- Each aircraft will call out several events. When the aircraft reaches its missed approach point it will declare "(ACID) We are going around, DME reading xx.x with airspeed yyy kts". When the aircraft reaches the 30R/24 intersection it will declare "(ACID) at intersection with airspeed yyy kts". When the leader declares it is at the intersection, the trailing aircraft will declare "(ACID) at DME xx.x with airspeed yyy kts". When the trailer reaches the intersection it will declare "(ACID) at intersection with airspeed yyy kts". *[Pilot or copilot on aircraft]*

- If the trailing aircraft is Flight Management System equipped, it will substitute the FMS reading to the intersection in place of the Distance Measurement Equipment readings above *[Pilot or copilot on aircraft]*

- In the tower a manual record will be taken of the events, times (as determined by the tower clock) and speeds (ground speeds) from the BRITE and the winds *[MITRE]*

- If there is an observer on board, when each of these events are declared, the observer will note the airspeed, the ground speed if the aircraft is Inertial Navigation System equipped and the DME. *[Observer on aircraft]*

The data reduction will be as follows:

- Aircraft separation when leader is at intersection and time separation between transits through the intersection from reduction of CDR data [after the fact]

- If the trailing aircraft has an FMS, then the separation will be known immediately

- From the DME positions, the separation when the leader is at the intersection can be found by calculation [near real time] *[MITRE]*

- From the clock times in the tower for scenario 1, the time between transit of the intersection by the two aircraft can be computed [near real time] *[MITRE]*

- The video tape can be used as a debriefing tool after the fly-in

- The DME positions, video tape, audio tape, and the CDR tape will be used to reconstruct the events and allow a validation of the MITRE model. *[MITRE]*

APPENDIX E

DETAILED RESULTS OF THE STAGGER CONTROLLER QUESTIONNAIRES

Questionnaires regarding stagger operations with the CRDA were administered during the period 14-20 April 1992 to TRACON and tower controllers who had experience with CRDA stagger. Representatives from the St. Louis Plans and Procedures Staff and MITRE met with controllers, supervisors and TMCs for the purposes of handing out the questionnaires, explaining the intent of the questionnaires, and answering any questions pertaining to the questionnaire items.

The formal evaluation via the questionnaires confirmed several findings which had surfaced during the informal day-to-day evaluation at St. Louis. The questionnaire responses also revealed findings in new areas, not previously identified during the informal evaluation. The questionnaire results are presented in this appendix.

E.1 RESULTS OF THE TRACON QUESTIONNAIRE

Of the 29 TRACON controllers who had experience with CRDA-assisted staggering, 23 were available during the questionnaire period and all responded to the questionnaire. In addition, responses were received from one supervisor and one TMC. On the average, the respondents had approximately 6 years FPL experience at St. Louis. Seventeen of the respondents indicated that they had more than 2 hours of experience using CRDA for stagger operations, while all but one of the other respondents indicated between 1/2 and 2 hours experience.

The questionnaires were filled out independently by each respondent, without discussion between respondents during the process. The intent was to obtain the independent opinion of each respondent, without the possible biases which could result if an interaction was allowed to ensue, with perhaps several respondents dominating the discussion and possibly exercising undue influence on the individual questionnaire responses.

E.1.1 Consensus Areas

After analyzing the questionnaire responses, it was clear that a consensus was reached on many of the areas addressed by the questionnaire. Those areas on which all or a sizable majority of the respondents agreed are described below:

- Eighty percent of the respondents indicated that the use of CRDA during staggering operations either does not affect the accomplishment of their other controller tasks, or that the use of CRDA actually makes the performance of their other controller tasks easier. 16 percent (i.e., 4 respondents) indicated that the use of CRDA "occasionally interferes" with the performance of their other controller tasks; only one respondent

indicated that the use of CRDA *"often interferes" with the performance* of his/her other controller tasks.

- The respondents unanimously indicated that no additional information is required in the ghost data block.

- Regarding the controllers' ability to distinguish ghost targets from actual aircraft, 88 percent of the respondents indicated that they had absolutely no difficulty in distinguishing between the two. Of the 3 controllers (12 percent) who indicated that they sometimes had difficulty distinguishing between the two, all reported that this occurred "very rarely".

- Regarding the possible need to use different ghost position symbols for tieing and stagger operations with CRDA, 83 percent indicated that use of the same symbol for both applications is satisfactory. Three respondents indicated that use of different symbols would be preferable, but not essential, while only one respondent indicated that using different symbols is essential.

- Eighty-Eight percent of the respondents indicated that they always use the display of ground speed in the ghost data block, while 12 percent reported that they sometimes suppress the ground speed display. No respondent indicated that he/she never uses the ground speed display.

- The respondents unanimously reported that the display of the ground speed in the ghost data block was operationally acceptable (i.e., that there was no confusion due to the fact that altitude is usually displayed in full or partial data blocks for real targets where ground speed is displayed in ghost data blocks).

- The respondents unanimously reported that no ARTS display functions, which were important to them, had been changed or deleted by the CRDA.

- On the subject of display clutter as a result of the ghost data blocks, 92 percent of the respondents indicated that the ghost data blocks either do not significantly contribute to display clutter; or that the ghost data blocks do contribute to display clutter, but the overall assistance provided by the CRDA during staggered approach operations outweighs the disadvantages presented by clutter. Only one respondent indicated that the additional clutter "significantly interferes" with his/her ability to use CRDA during staggered approach operations. One other respondent indicated that the ghost data block does contribute to clutter and increases workload by having to change leader directions, "but it does not happen at a critical point often."

- Only four respondents indicated that they had experienced a transition directly from tie operations to stagger operations, or vice versa, and 3 of the 4 indicated that the transition was accomplished smoothly.

- All but one of the respondents (96 percent) indicated that the display and format of CRDA-related information in the Systems Area of the ARTS display is adequate. One controller indicated that the displayed data could be condensed to simply indicate whether or not CRDA is on, and that the display of the runway configuration was superfluous.

E.1.2 Non-Consensus Areas

The respondents did not agree on several items addressed by the questionnaire. The areas where the respondents did not reach a consensus of opinion are identified below:

- Forty-Four percent of the respondents reported that "CRDA is essential" to providing consistent and accurate staggers over a sustained period of time. 52 percent of the respondents indicated that "CRDA is very helpful" in performing the task; however, they felt that they could perform the task on a sustained basis without it, but that their workload would be increased. One respondent indicated that he/she could perform staggering just as well without CRDA, and that his/her workload would be about the same. No respondent chose a response which indicated that CRDA adversely affected his/her ability to perform the staggering task.

- Regarding the use of CRDA to perform staggering in adverse wind conditions, 24 of the 25 respondents indicated that they had opportunities to use CRDA-assisted staggering under such conditions. Of those, 38 percent indicated that wind conditions are sometimes a factor in achieving satisfactory staggers, but after a short adjustment period they could "easily accommodate wind conditions." 50 percent of the respondents reported that wind conditions are sometimes such that it is difficult to achieve good staggers, although they could do it. One respondent indicated that adverse wind conditions do not affect his/her ability to achieve satisfactory staggers, while two other respondents indicated that they were sometimes unable to achieve the required staggers due to wind conditions.

- In response to a question as to whether ghost targets are displayed at the right time, 48 percent of the respondents indicated that they were, and 52 percent reported that the ghost targets were sometimes displayed too late. Of those that indicated that the display was too late, all but one indicated that this occurs "sometimes, but not often enough to adversely affect my control operation."

E.1.3 Other Opinions Expressed

In addition to the specific questions to which the controllers were asked to respond, several concerns and opinions were expressed by t'.. TRACON controllers. Each of the concerns and opinions listed below was expressed by several questionnaire respondents:

- Several TRACON respondents indicated their opinion that the TMC and the TRACON TSA needed to be involved early when the decision is made to transition into CRDA-assisted stagger operations in order to properly establish the initial traffic flow, and that they need to be more directly involved throughout stagger operations to adjust traffic flows as necessary.

- Several respondents expressed a concern regarding the difficulty in developing and maintaining proficiency in the use of CRDA for stagger operations, since the opportunities for its use are limited.

E.1.4 Recommendations

Based upon the analysis of the questionnaire responses, the following actions were recommended:

- Regarding the concern of some respondents that the ghost data blocks were sometimes displayed too late, it was recommended that further emphasis be placed on the need for timely scratchpadding of runway information. This recommendation is based on comments from several respondents that they felt late scratchpadding was the cause of the problem, rather than incorrect shape of the ghosting region. If this continues to be a concern after more experience is gained with the aid, then a change to the ghosting region should be considered, although this is not expected to be necessary. (Note that most respondents who indicated that the ghost data blocks were sometimes displayed too late also indicated that this happened "not often enough to adversely affect my control operation.")

- With respect to CRDA-assisted stagger operations in adverse wind conditions, no specific recommendation was offered. The expectation is that additional experience with CRDA stagger operations will result in most controllers becoming adept at using the aid in adverse winds. If not, then it may be necessary to inhibit the use of staggering operations for certain wind conditions which are particularly difficult for the controllers to handle.

- Regarding the concern expressed by several respondents that the TMC and TSA should be involved earlier in transitioning into stagger operations, and that they should be more directly involved during stagger operations, St. Louis Plans and Procedures personnel were already aware of this and had taken action to correct the problem. However, this issue will be carried forward as guidance material for the implementation of CRDA at other sites (see appendix G).

- On the issue of acquiring and maintaining proficiency in the use of CRDA for staggering, two factors are expected to alleviate this problem to some extent. First, with the completion of Phase IV of the evaluation at St. Louis, the facility will be able to use the CRDA for staggering during all IFR conditions down to Category I weather

minima. This should provide additional opportunities to use the aid, since during the Phase IV evaluation use of the aid was constrained by the need to satisfy the Phase IV weather step-down criteria. Second, when St. Louis receives the ARTS IIIA, A3.05 version of CRDA, and if the facility could obtain a localizer for runway 6, then the facility would be able to use CRDA for staggering in 1 6/12 runway configuration as well as the 24/30 configuration. This will also provide additional opportunities to use the aid. If proficiency continues to be a concern, however, periodic proficiency training in the use of CRDA-assisted stagger operations should be considered.

E.2 RESULTS OF THE TOWER QUESTIONNAIRE

Of the 13 tower controllers who had experience with CRDA-assisted staggering, 10 were available during the questionnaire period and all responded to the questionnaire. Responses were also received from two tower supervisors and one staff specialist. On the average, the respondents had approximately 6 years of experience certified as a local controller at St. Louis. Seven of the ten controllers indicated that they had between 1/2 - 2 hours experience working the LC-N position during CRDA staggering operations, while three indicated more than 2 hours experience. Eight of the ten controllers reported that they worked the LC-3 (monitor) position during CRDA stagger operations between 1/2 - 2 hours, with one controller indicating less than 1/2 hour experience and another indicating more than 2 hours experience.

As in the case of the TRACON questionnaires, the tower questionnaires were filled out independently by each respondent, without discussion among respondents during the process.

E.2.1 Areas of Consensus

After analyzing the questionnaire responses, it was clear that a consensus was reached on several of the areas addressed by the questionnaire. Those areas on which a sizable majority of the respondents agreed are described below:

- 11 respondents (~85 percent) indicated that the DBRITE displays adequately present ghost target data to permit them to perform their controller tasks during stagger operations. Of the 2 respondents that disagreed, one requested a software change that is beyond the scope of the A3.05 (i.e. national) version of CRDA; and the other requested that the ghost target be displayed longer, a problem which had already been corrected at St. Louis by reducing the size of the automatic (target) drop zone.

- 12 of the 13 respondents (~92 percent) indicated that they had "absolutely no difficulty in distinguishing" between ghost targets and actual aircraft. The one respondent who reported some difficulty indicated that this occurred "occasionally".

E.2.2 Non-Consensus Areas

The respondents did not agree on several items addressed by the questionnaire. The areas where the respondents did not reach a consensus of opinion are identified below:

- 9 respondents (~69 percent) indicated that they felt that tower/TRACON coordination appeared adequate in initiating stagger operations with CRDA and during operations with CRDA. 2 respondents (~15 percent) reported that the coordination is generally acceptable, but can sometimes be improved. 2 other respondents indicated that tower/TRACON coordination needed to be improved. Some of the suggested areas of improvement were:

  -- The TRACON needs to be more specific as to when and with which aircraft the stagger will begin

  -- The tower and TRACON supervisors should better coordinate to determine the proper stagger distance to use

  -- CRDA stagger operations should be initiated prior to an inbound rush, rather than "on the fly"

  -- There should be improved coordination between the TRACON and the tower on "pullouts" (i.e., aircraft which are broken out of the arrival stream due to insufficient stagger)

- The questionnaire contained a question (Question 1 of section II of the questionnaire in section E.4) which was intended to elicit feedback on whether it was easier for controllers to perform their job with CRDA <u>given</u> that the controllers were required to perform stagger operations in IFR conditions (i.e., as opposed to performing staggering without the use of CRDA). From several of the narrative responses to this question, it was evident that some respondents misinterpreted the question, and thought the question was eliciting a comparison between performing stagger operations with CRDA during IFR vs. performing single-stream arrival operations to runways 30L/R (i.e., the normal mode of operation in IFR conditions before the introduction of CRDA). With this apparent misinterpretation, when asked "do you expect your job will be made easier because of the CRDA?", about half of the respondents indicated "about the same as without CRDA" and about half responded that their job would be "more difficult". Since some of the respondents were apparently comparing CRDA-assisted stagger operations with single-stream arrival operations, it is not surprising that nearly half felt that their job would be more difficult, since CRDA stagger operations do require a higher controller workload than does single-steam in-trail operations. Increased controller workload is one of the costs associated with achieving the higher arrival capacity which is possible with

CRDA. However, as more experience and proficiency is gained with CRDA in stagger operations, it is expected that the difference in workload between CRDA stagger operations and single-stream arrival operations will become progressively smaller.

- When asked how often they had to intervene by issuing a speed command to achieve a satisfactory stagger while working the LC-N position, 5 respondents indicated "occasionally", 6 indicated "often", 1 indicated "rarely" and 1 indicated "never have needed to" (although this respondent was a supervisor). The expectation was that the majority of responses would indicate that intervention was rare (presuming the TRACON was delivering accurate staggers). In follow-up discussions with Plans and Procedures Staff personnel at St. Louis to interpret the responses to this question, it was indicated that the degree of tower intervention depends largely on how the TRACON is operating. For example, if the TRACON is using a relatively large stagger and the winds are calm, then the tower may not need to intervene at all, or very rarely; whereas, if the TRACON is running with a minimum stagger and/or the winds are a significant factor, then the tower may have to intervene often.

- When the same question regarding the degree of intervention required to achieve accurate staggers was asked of controllers who had worked the LC-3 position, 3 responded "rarely", 7 responded "occasionally", and 3 responded "often". Presumably the same rationale as that of the previous question applies in explaining this diversity of opinion.

E.2.3 Other Opinions Expressed

In addition to the specific questions to which the controllers were asked to respond, several concerns and opinions were expressed by the tower controllers. Each of the concerns and opinions listed below was expressed by several questionnaire respondents:

- Concern was expressed about the anticipated difficulty of getting departures out during CRDA stagger operations. While CRDA operations up to the time of administration of the questionnaires had not adversely impacted departure operations, an adverse impact during low visibility weather conditions had been anticipated by evaluation personnel since the start of the St. Louis evaluation. One of the objectives of the evaluation was to determine the magnitude of the impact, and to develop the best operational strategy for dealing with this. However, there has not yet been opportunities to operate CRDA at low visibility conditions to meet this objective.

- Several respondents mentioned a need for improved coordination on pullouts and a better definition of pullout procedures. Follow-up discussions between Plans and Procedures Staff personnel and the controllers who expressed this opinion revealed that several controllers wanted standard pullout procedures to be defined. However,

Plans and Procedures personnel indicate that the use of standard pullout procedures is not possible at St. Louis, and are not used during normal operational situations.

- Several respondents indicated that they were not yet comfortable with CRDA staggering operations due to the limited amount of time they had been used, and, as in the case of the TRACON respondents, the subject of developing and maintaining proficiency was raised.

- Lingering concern was expressed about whether the missed approach procedures to be used with CRDA would provide adequate separation at the projected runway intersection in the case of consecutive missed approaches.

- The need for additional staffing (i.e., the LC-3 position) was mentioned by several respondents. However, this appears to be more of a facility management issue, rather than a controller concern.

- The need for more simulation training before using CRDA in live operations was mentioned by several respondents.

E.2.4 Recommendations

Based upon the analysis of the questionnaire responses, the following actions were recommended:

- For national implementation of CRDA, each facility that intends to use the CRDA in the staggering mode of operation should consider the use of a monitor position during staggering operations for a period of time (to be determined by the facility) until sufficient experience is acquired with the aid. This recommendation is prompted by the higher-than-expected degree of speed control intervention by the local controller and the monitor controller during the evaluation at St. Louis.

- While it is not possible to use standard pullout procedures at St. Louis during CRDA stagger operations, other sites at which CRDA will be used for stagger operations should consider the use of such procedures in order to simplify and improve the coordination between the tower and the TRACON.

- With respect to improving tower/TRACON coordination when transitioning into CRDA stagger operations and during stagger operations, St. Louis has already taken action to address the specific suggestions offered by the tower respondents (see section E.2.2). The role of the TMC and the tower and TRACON supervisors will be highlighted in the guidance material prepared for national implementation of the CRDA. This will include the specific suggestions offered by the St. Louis controllers.

- Regarding the concern with respect to tower controller proficiency in the use of CRDA, the same recommendation is offered as was presented in section E.1.4 for TRACON controllers.

- Regarding the concern of several controllers about the adequacy of the separation at the projected runway intersection in the case of consecutive missed approaches during staggering operations, the following steps are recommended for the implementation at other sites which will use CRDA for stagger operations:

  -- As part of initial classroom training, the controllers, TMCs and controller supervisors should be given a brief presentation on the extensive missed approach simulation analysis which has been conducted, and a brief summary of the live flight demonstration which was conducted at St. Louis.

  -- Tower controllers should be given ETG training early in the training process, and the training should be more extensive than was initially provided by St. Louis.

E.3 TRACON QUESTIONNAIRE

The TRACON questionnaire used during Phase IV of the CRDA evaluation is shown on the following pages.

E.4 TOWER QUESTIONNAIRE

The tower questionnaire used during Phase IV of the CRDA evaluation is shown on the following pages.

QUESTIONNAIRE ON STAGGER OPERATIONS WITH THE CONVERGING RUNWAY DISPLAY AID (CRDA)

In all sections, please fill in the requested information, or check the answer which most closely matches your response. For Sections II and III, please use the last page of the questionnaire if you need more space to respond to any question.

SECTION I

GENERAL INFORMATION

1. Name: ______________________________

2. Date: ______________________

3. Years FPL: ________________

4. Length of time certified as an STL feeder or final approach controller: _______________

5. Approximate number of hours you have used CRDA for actual stagger operations:

- ☐ (a) Less than 1/2 hour
- ☐ (b) 1/2 - 2 hours
- ☐ (c) More than 2 hours

6. Position(s) worked with CRDA in stagger operations (check all that apply):

- ☐ (a) North Feeder
- ☐ (b) Final approach to Runway 24
- ☐ (c) Final approach to Runway 30R
- ☐ (d) South Feeder

SECTION II

GENERAL QUESTIONS ON USE OF THE CRDA IN STAGGER OPERATIONS

1. Assuming that you are required to provide dependent, converging (i.e. staggered) approaches to Runways 24 and 30R in IFR conditions (2 mile/5 mile stagger), which of the following statements best applies:

- ☐ (a) Use of the CRDA is essential to providing consistent and accurate staggers over a sustained period of time
- ☐ (b) The CRDA is very helpful in performing the task; however, I believe I could perform the task on a sustained basis without it, but my workload would be increased
- ☐ (c) I believe I could perform the task just as well without the CRDA, and my workload would be about the same
- ☐ (d) Use of the CRDA adversely affects my ability to perform the staggering task
- ☐ (e) Other: ____

2. Do you believe that your overall opinion regarding the utility of the CRDA for conducting staggered approaches has changed since you first used the aid in actual operations?

- ☐ (a) My opinion of the CRDA is considerably more favorable now than initially
- ☐ (b) My opinion of the CRDA is somewhat more favorable now than initially
- ☐ (c) My opinion now is basically the same as it was initially

☐ (d) My opinion of the CRDA is <u>somewhat less favorable now</u> than it was initially

☐ (e) My opinion of the CRDA is <u>considerably less favorable now</u> than initially

If your opinion has changed, what do you believe influenced the change?:____________________

____

3. We want to find the best ways to introduce the CRDA to other facilities. When you <u>first</u> began to use CRDA during actual operations to conduct staggered approaches, what were your <u>first reactions and general opinion</u> about the operational utility of the aid?

☐ (a) Very useful

☐ (b) Useful

☐ (c) No firm opinion initially

☐ (d) Not useful, but also not harmful to performing my control functions

☐ (e) Not useful, and interfered with performing my control functions

☐ (f) Other:____________________

____

____

If your response was (e), please describe the problem(s) which you felt were introduced by the CRDA:____________________

____

____

4. What are the effects on your other controller tasks when using the CRDA to conduct stagger operations?

- ☐ (a) Use of the CRDA <u>allows easier performance</u> of my other controller tasks
- ☐ (b) Use of the CRDA <u>does not affect</u> the accomplishment of my other controller tasks
- ☐ (c) Use of the CRDA <u>occasionally interferes</u> with the performance of my other controller tasks
- ☐ (d) Use of the CRDA <u>often interferes</u> with the performance of my other controller tasks

If your response was (c) or (d), which of your controller tasks are adversely affected? ______________________________

____

____

5. Do you find that wind conditions affect your ability to achieve satisfactory staggers with the CRDA?

- ☐ (a) I have had <u>no opportunity</u> to use the CRDA for stagger operations in adverse wind conditions
- ☐ (b) Wind conditions <u>do not affect</u> my ability to perform satisfactory stagger operations with the CRDA
- ☐ (c) Wind conditions are <u>sometimes a factor</u>, but after a short adjustment period I find that I <u>can easily accommodate wind conditions</u>
- ☐ (d) Sometimes wind conditions are such that it is <u>difficult to achieve good staggers</u>, although I can do it
- ☐ (e) Sometimes I am <u>unable to achieve the required staggers</u> due to wind conditions

☐ (f) Other: ____________________

____

If your response was (d) or (e), what wind conditions (direction and magnitude) make staggering difficult or unfeasible at all with stagger operations to Runways 24 and 30R?

____

6. Are there any other factors which prevent you from achieving consistent, accurate staggers with the CRDA, or which make it difficult for you to do so (e.g., speed differentials on final, coordination with other controllers)? If so, please identify them: ____________________

____

____

7. Have you ever experienced a transition directly from CRDA tie operations to stagger operations, or vice versa?

☐ (a) Yes

☐ (b) No

If your response was (a) (Yes), was the transition smooth?

☐ (i) Yes

☐ (ii) No

If the transition was not smooth, what were the problems you observed? ____________________

____

____

SECTION III

SPECIFIC QUESTIONS RELATED TO THE DISPLAY AND DATA ENTRY FEATURES OF THE CRDA

1. Is any additional information necessary in the ghost data block? (I.e., in addition to the ghost position symbol, leader, ground speed, and heavy jet indicator)

☐ (a) No

☐ (b) The following information is required: ______________________

____

☐ (c) The following information is desired, but not required: ________

____

If your response was (b) or (c), please indicate why you believe the additional information is required or desired: ______________________

____

2. Do you have difficulty in distinguishing ghost targets from actual aircraft?

☐ (a) Absolutely no difficulty in distinguishing between the two

☐ (b) I have difficulty in distinguishing between the two

☐ (i) Often

☐ (ii) Occasionally

☐ (iii) Very rarely

If (b) was selected, do you have any suggestion on how to better distinguish between ghost targets and actual aircraft?

____

____

3. Do you believe it is important to use a different ghost position symbol for tie and stagger operations?

☐ (a) Using the same symbol is satisfactory

☐ (b) Using different symbols would be preferable, but not essential

☐ (c) Using different symbols is essential

4. Ghost targets are displayed when (1) the associated aircraft enters a predefined geographic area and (2) when the assigned runway has been entered into the scratchpad area. Are the ghost targets displayed at the right time?

☐ (a) Yes

☐ (b) Displayed too early

☐ (i) Sometimes, but not often enough to be a nuisance

☐ (ii) Often enough that I consider it to be a nuisance

☐ (c) Displayed too late

☐ (i) Sometimes, but not often enough to adversely affect my control operation

☐ (ii) Often enough that it adversely affects my control operation

5. The current system allows the individual controller to request or suppress the display of ground speed for all ghost targets (i.e., not on an individual ghost basis). Which of the following best describes your use of the ground speed display for ghost targets?

☐ (a) I always use the ground speed display

☐ (b) <u>I sometimes suppress</u> the ground speed display

☐ (c) <u>I never use</u> the ground speed display

If your response was (b), please identify the conditions when you typically suppress the display:____

6. Is the display of the ground speed in the ghost data block operationally acceptable? (I.e., is there any confusion since altitude is usually displayed in full or partial data blocks for real targets where ground speed is now displayed in ghost data blocks?)

☐ (a) Acceptable

☐ (b) Not acceptable

If your response was (b), do you have an alternative to suggest?

7. Are there any ARTS display functions which have been changed or deleted by the CRDA and <u>which are important to you</u>?

☐ (a) No

☐ (b) Yes

If your response was (b), please identify the function(s) and describe the effect on your control tasks:____

8. The display of ghost data blocks is new information presented on the ARTS display. To minimize display clutter, the ghost data blocks can be offset independently from the data blocks for actual aircraft. Which statement most accurately describes your opinion regarding display clutter?

☐ (a) The ghost data blocks do not significantly contribute to display clutter

☐ (b) The ghost data blocks contribute to display clutter, but the overall assistance provided by the CRDA during staggered approach operations outweighs the disadvantage presented by clutter

☐ (c) The additional clutter significantly interferes with my ability to use the CRDA during staggered approach operations

☐ (d) Other: ______________________________

If your response was (b),(c) or (d), do you have any suggestions as to how to reduce the clutter, yet still display the ghost information?

____

____

9. When the CRDA has been enabled, the Systems Area of the ARTS radar display contains "Ghosts On", a "T" or "S" to indicate Tie or Stagger operation in effect, and the runway configuration associated with CRDA operations. Is the display of this information and the format of the display adequate?

☐ (a) Adequate as is

☐ (b) Display should be modified

If (b) was selected, please indicate how you would modify the display: ______________________________

____

10. In addition to any suggestions you may have made above, do you have any other suggestions or recommendations on how to improve the operational utility of the CRDA for stagger operations?

____

____

____

11. In your opinion, are there any operational problems associated with the use of the CRDA for stagger operations, beyond those addressed by the above questions? If so, what are they? ______________________________
____
____

CONTINUATION SHEET:

If you need more room to respond to any of the questions, please indicate the Section number (II or III) and the question number, and continue your response on this sheet.

TOWER QUESTIONNAIRE ON STAGGER OPERATIONS WITH THE CONVERGING RUNWAY DISPLAY AID (CRDA)

In all sections, please fill in the requested information, or check the answer which most closely matches your response. For Sections II and III, please use the last page of the questionnaire if you need more space to respond to any question.

SECTION I

GENERAL INFORMATION

1. Name: ________________________________

2. Date: __________________________

3. Years FPL: ______________

4. Length of time certified as an STL local controller: ______________

5. For approximately how many hours have you used the CRDA during actual stagger operations?

- When working the LC-N position

  ☐ (a) Less than 1/2 hour

  ☐ (b) 1/2 - 2 hours

  ☐ (c) More than 2 hours

- When working the LC-3 (monitor) position

  ☐ (a) Less than 1/2 hour

  ☐ (b) 1/2 - 2 hours

  ☐ (c) More than 2 hours

SECTION II

GENERAL QUESTIONS ON THE USE OF THE CRDA IN STAGGER OPERATIONS

1. Assume that the facility is required to stagger arrivals to runways 30R and 24 in IFR conditions. In this situation, do you expect your job will be made easier because of the CRDA?

☐ (a) Much easier

☐ (b) Somewhat easier

☐ (c) About the same as without the CRDA

☐ (d) More difficult

If your response was (d), please explain: ________________________________

____

____

2. What are your views regarding tower/TRACON coordination in initiating stagger operations with CRDA and during operations with CRDA?

☐ (a) The current coordination procedure appears adequate

☐ (b) Coordination between the tower and the TRACON is generally acceptable, but can sometimes be improved

☐ (c) The tower/TRACON coordination procedure needs to be improved

If your response was (b) or (c), how would you recommend that the coordination be improved? ________________________________

____

____

3. When working as the LC-North, how often have you had to intervene by issuing a speed command to achieve or maintain a satisfactory stagger?

- ☐ (a) Never have needed to
- ☐ (b) Rarely
- ☐ (c) Occasionally
- ☐ (d) Often

4. When working as the LC-3 (monitor), how often have you had to intervene by issuing a speed command to achieve or maintain a satisfactory stagger?

- ☐ (a) Never have needed to
- ☐ (b) Rarely
- ☐ (c) Occasionally
- ☐ (d) Often

SECTION III

SPECIFIC QUESTIONS RELATED TO THE TOWER DISPLAY FEATURES OF THE CRDA

1. Do the DBRITE displays adequately present ghost target data to permit you to perform your controller tasks during stagger operations?

☐ (a) Yes

☐ (b) No

If your response was (b), what recommendations would you make for improving the display of ghost target data on the DBRITES? ______________

____

____

2. Do you have difficulty in distinguishing ghost targets from actual aircraft?

☐ (a) Absolutely no difficulty in distinguishing between the two

☐ (b) I have difficulty in distinguishing between the two

  ☐ (i) Often

  ☐ (ii) Occasionally

  ☐ (iii) Very rarely

If (b) was selected, do you have any suggestion on how to better distinguish ghost targets and actual aircraft? ______________

____

____

3. In addition to any suggestions you may have made above, do you have any other suggestions or recommendations on how to improve the operational utility of the CRDA for stagger operations in the tower?

____

____

____

4. In your opinion, are there any operational problems associated with the use of CRDA for stagger operations in the tower, beyond those addressed by the above questions? If so, what are they? ______________

____

____

CONTINUATION SHEET:

If you need more room to respond to any of the questions, please indicate the Section number (II or III) and the question number, and continue your response on this sheet.

APPENDIX F

USER RESPONSES TO CRDA

Attached are written aviation user responses which were received during the Phase IV evaluation from TWA (Western Region), the Air Transport Association of America (ATA), and Wetterau Incorporated. Also, as mentioned in section 5.4.3.3, a TWA representative verbally stated that 6 January 1992, when CRDA was used for stagger operations, was the first time that St. Louis had IFR conditions almost all day and the airline experienced no flight cancellations.

TWA

Trans World Airlines, Inc.

Post-it™ brand fax transmittal memo 7671	# of pages ▸ 1
To Joe Snyder	From Wendell Rone
Co.	Co. TWA / STL
Dept.	Phone # 429 9452
Fax # 427-2576	Fax #

January 31, 1992

Mr. Joe Snyder
FAA Tower
STL

We have been very pleased with the CRDA operation during the recent test. All our feedback has been positive.

We encourage you to continue with the test at the next weather level planned.

If you require any further information, please call.

W. H. Rone

W. H. Rone
General Manager-Flying
Western Region

Air Transport Association **ata** OF AMERICA

Central Regional Office
2128 South Wolf Road
Des Plaines, Illinois 60018
Phone (708) 299-7690
FAX (708) 299-7694

January 30, 1992

Joe G. Hokit, Manager
St. Louis ATCT
10805 Natural Bridge Road
Bridgeton, MO 63044

Dear Mr. Hokit

I am writing this letter inquiring into the status of the CRDA testing at your facility. It was our understanding, that after 125 approaches at 700 and 2, the minimums for CRDA would be lowered. We strongly support lowering the minimums to 200 and 1/2 at this time.

Further postponement in lowering the minimums is unnecessary, and will delay the program nation wide. The CRDA is a valuable tool in increasing airport capacity, not only at St. Louis, but throughout the country. Again, I urge you to proceed with lowering the CRDA minimums at the earliest possible time.

Sincerely,

John J. Baldwin,
Assistant Director

cc: AA - R. Harmon
D. Kneram
C. Price
CO - T. Jones
D. Osmundson
DL - D. Carr
R. Shutack
FM - R. Giordano
B. Kelley
J. Wharton
NW - R. Wylie
TW - C. Hollenbeck
D. O'Connell
W. Roen
UA - B. Cotton
US - D. Bernier
M. Dodd
WN - D. Foster
B. Self
P. Sterbenz
DHL - J. Code
UPS - D. Doyen
ATA - R. Fleming
J. Ryan
ACE-500

\stl\crdamin.ltr

Wetterau Incorporated

30 Jan 1992

Mr. Joe Hokit
FAA
St. Louis, Missouri

Dear Joe;

Wetterau Incorporated on behalf of the NBAA and other general aviation operators in St. louis, supports the continued evaluation of the CRDA. We endorse immediate lowering of the test minimums to 500 feet or 3/4's of a mil. We further encourage the FAA to count the approaches above the required 125 for the first phase test as part of the second phase total. We further believe that the FAA should count any approach between 500 and 3/4 and 1000 or 2 miles meeting the objectives of the second phase testing.

We see the CRDA implementation as the most productive step to increased IFR capacity at St. Louis in many years. The cost saving to the operators are enormous and we trust the FAA will work with all diligence to complete the testin at the lowest minimums.

Sincerely,

WETTERAU INCORPORATED
Joe Lintzenich
First Vice President and Chief P

APPENDIX G

GUIDANCE MATERIAL FOR THE NATIONAL IMPLEMENTATION OF CRDA

The purpose of this appendix is to document those lessons learned during the operational evaluation of CRDA which can be used to guide sites which plan to implement CRDA when the national version of CRDA is released as part of ARTS IIIA, Version A3.05. The material is based primarily on the experiences gained during the CRDA evaluation at St. Louis. It is complemented by lessons learned during June - November 1991 as part of a "paper exercise" to prepare for the implementation of CRDA and DCIAs at Philadelphia. The purpose of the Philadelphia exercise was to determine the schedule and complexity of the task of preparing for the implementation of CRDA, and to provide another source (i.e., other than St. Louis) as the basis for developing guidance material for the national implementation of CRDA.

As part of their exercise, Philadelphia staff prepared weekly status reports as a means of reviewing progress and planning for future activities. These reports identified in detail the steps taken to prepare for CRDA operational use and highlighted any significant lessons learned. The material prepared by Philadelphia was incorporated into the first category of guidance presented in this appendix.

It is recommended that material presented in this appendix be considered by each site in preparing for, and implementing, CRDA. While some of the steps described below are tantamount to being requirements in the sense that a site could not prepare for and implement CRDA without performing the step (defining an appropriate "ghosting region" for each CRDA application, for example), the intent is not to define requirements. The steps identified reflect the characteristics of the sites from which the material was developed, as a result of the CRDA evaluation at St. Louis and the paper exercise at Philadelphia. The individual facilities at which CRDA will be implemented will have their own unique characteristics which will each require site to tailor the steps described to their own facility.

In presenting the material in this appendix, it is assumed that representatives from the TRACON and tower, and representatives of the associated Air Traffic Regional Office, have been briefed on the CRDA concept, and that basic CRDA-related terms (such as "reference point", "ghosting region", etc.) are understood.

The guidance material is presented in four categories as follows:

- Preparing for operational use of CRDA
- CRDA training
- Transitioning into operational use of CRDA

- CRDA operational use

In general, many of the activities described in the first two categories may be performed in parallel, while the activities associated with the last two categories tend to be more serial in nature.

A. Preparing for Operational Use

1. The facility should identify a CRDA point of contact who will oversee and coordinate all CRDA-related activities; an attempt should be made to assign someone to this role who will remain assigned to the task throughout the planning, training, and transition of the CRDA into operational use.

2. Determine the set of VFR and/or IFR applications for which CRDA will be used at the facility, and the pertinent runway configurations for each application, when applicable (e.g., an application to use CRDA to control traffic arriving at several satellite airports may not require runway configuration information). In performing this task, consider applications which have been defined for use at other sites as a source of potential applications.

3. For each CRDA application, the following need to be determined: the associated reference points, the dimensions of the ghosting qualification region, the ghosting qualification criteria, and the ghosting display symbology. The appropriate ARTS adaptation data should be generated accordingly.

4. Using the Dependent Converging Instrument Approaches National Order as a guideline, determine any runway or speed restrictions required to conduct CRDA-assisted stagger operations.

5. Analyze controller operational responsibilities for each application of CRDA. Identify any necessary modifications to controller responsibilities, and possibly identify new controller positions to be staffed. Further, identify any control position reconfigurations required for a CRDA application (e.g., St. Louis reconfigured TRACON control positions so that the 30R and 24 control positions were adjacent to each other during stagger operations to facilitate coordination).

6. Assure that all personnel are fully aware of their responsibilities for transitioning into CRDA operations, during CRDA operations, and for transitioning out of CRDA operations. Coordination responsibilities should be especially emphasized.

   a. Produce a Local Notice (see St. Louis' Notice [Reference 12] as an example) or update facility directives

b. Provide briefings to controller teams, prior to the operational use of CRDA and on an ongoing basis as necessary.

7. Identify hardware, software or procedural changes required as a result of items 4 and 5 above, and implement those changes. For example, if a monitor controller is to be used for CRDA stagger operations (see item C.3 below), a voice frequency channel may need to be provided, possibly with an override capability of the local controller's frequency.

8. Determine whether airspace changes are required for using CRDA

   a. If a particular CRDA application is expected to be used relatively infrequently, then avoid designing the airspace to optimize for the small percent of time when CRDA will be used, if that will cause "normal" operations to become overly complicated

   b. Again, if CRDA is expected to be used relatively infrequently, attempt to minimize the differences between "non-CRDA airspace" and "CRDA airspace" so controllers can more easily remember the difference when CRDA is used.

9. If airspace changes are required, attempt to define them early to allow sufficient lead time for the design, production, delivery and installation of new video maps for the TRACON. These video maps should be installed prior to the start of CRDA training.

10. Identify all other CRDA-related lead time items at an early date, and estimate the required lead time for each. Examples include:

    a. Modification of approach plates/procedures defining straight-out missed approaches (if not already in use at the site)

    b. Environmental impact studies/issues if operations with CRDA will affect the noise level footprints of the local community

    c. Notices to Airmen, Letters to Airmen, Letters of Agreement

    d. If the site has DBRITE displays with analog video maps, evaluate the suitability of such maps for CRDA operations and determine whether digital video maps are required. If so, arrange for the production, delivery, and installation of these video maps.

   e. Scheduling of the ETG for purposes of CRDA training[8]

11. Perform early and ongoing coordination (including regularly scheduled telephone conferences, if necessary) regarding upcoming implementation and operational use of the CRDA

   a. With the Quality Through Partnership staff at the facility (successor to the Facility Advisory Board)

   b. With the local representatives of the National Air Traffic Controllers Association (NATCA)

   c. With the Region

   d. With local aviation users

   e. With local airport management

   f. With adjacent or nearby facilities, if necessary

B. Training

1. Assure that adequate time is available to the site training staff to become familiar with CRDA, and to develop an adequate training program. Assure also that sufficient access to the ETG facility is available to the training staff for this purpose.

2. Depending on the size of the facility's complement of training staff, the number of personnel to be trained in CRDA, and the amount of ETG laboratory time available for training, the facility may want to consider a "cadre training" approach as was used at St. Louis (see section 5.1.2.1).

3. Configure the system so that ETG training can be conducted concurrent with use of the CRDA operationally.

4. Prior to the start of training, an informal evaluation of the suitability of the airspace, CRDA-related procedures, the ghosting region(s), the ghosting qualification criteria, and the ghosting symbology should be performed in the ETG. These should then be fine-tuned as necessary, prior to the use of CRDA in live operations, to reflect controller feedback received during the training.

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8 Those facilities that do not have an ETG training capability we will need to adapt the guidance material to the training methods normally used by the site.

5. Suggested training approach:

   a. Short classroom training for all controllers (TRACON and tower) and supervisory personnel. In addition to covering such items as (1) the CRDA concept and relationship to DCIAs, (2)CRDA airspace modifications, (3) the controller's role in CRDA operations (general description), etc., the classroom training should address the following specific points:

      - Advise the controllers that most of their questions will be better answered during the hands on portion of the training.

      - To preempt or minimize questions on the subject of providing adequate separation in the case of consecutive missed approaches when running CRDA-assisted stagger operations, or any other potential safety issues, explain that the controller's role is to provide an adequate stagger, and that if a satisfactory stagger is provided, then separation at the intersection is guaranteed even in the case of consecutive missed approaches. Briefly describe the extensive analysis that has been done on this, and the live flight tests performed at St. Louis.

      - Emphasize to the controllers that the minimum allowable stagger between the ghost and the real aircraft is only enforced at the threshold.

      - Review any aircraft speed restrictions and/or runway utilization restrictions associated with the use of CRDA.

   b. Then proceed to individual ETG training for both TRACON and tower controllers. The focus of tower controller training would be to provide practice in speed adjustments to achieve satisfactory staggers at the threshold. This may be necessary during times when the TRACON is running with minimum staggers in adverse wind conditions.

6. Assure that controller supervisors are given adequate training in CRDA, including ETG training, so that they can assist during CRDA operations by answering controller questions and by generally facilitating the assimilation of CRDA into normal operations. Stress the positive role they can play during the early phases cf CRDA use if they understand the concept and operational use of the CRDA.

7. In the training provided to the TMCs and the TRACON supervisors, the importance of their roles in initially establishing the traffic streams at the start of stagger operations, and in identifying and resolving special problems during stagger operations, should be emphasized. Several specific points to cover during this training include the following:

-- The TRACON should be specific as to when and with which aircraft the stagger will begin

-- The tower and TRACON supervisors should coordinate to determine the proper stagger distance to use

-- If possible, CRDA stagger operations should be initiated prior to an inbound rush, rather than "on the fly"

-- There should be coordination between the TRACON and the tower on "pullouts" (i.e., aircraft which are broken out of the arrival stream due to insufficient stagger or other reasons)

8. Perform the training as close to actual operational use of the CRDA as possible. If CRDA is to be used for several different applications, attempt to schedule ETG training so that the training for each application will be performed as close as possible to actual operational use of that application.

9. Regarding the types of scenarios to be used during ETG training, consider the pros and cons of using "benign" scenarios (little or no wind, small differential in aircraft speeds) vs. the use of both benign and "stress" scenarios (various wind conditions, large speed differentials). I.e., decisions will need to be made to determine the level of realism which should be used in training controllers. Also, the scenarios used should represent realistic traffic levels for the CRDA application being trained, and the "scenario buildup time" should be minimized to make the most efficient use of the ETG facility resources, and trainer and trainee personnel resources.

10. If more than one ETG training team is to be used, it is important that the training personnel from the different training teams, even if they are working different shifts, coordinate to assure consistency of training across the teams.

11. Consider the development of video tapes for TRACON and tower controllers to provide a means of readily-available individual refresher training. (Examples of such training tapes are available from the St. Louis facility.)

12. Where possible, try to draw analogies between pre-CRDA operations and post-CRDA operations, from the point of view of controller actions.

13. Depending on the frequency of use of each of the CRDA applications at the facility (as determined after several months of operational use by the facility), consider the possible need for periodic proficiency training in CRDA.

C. Transitioning Into Operational Use

1. If the set of CRDA applications for a facility contains both VFR and IFR applications, consider operational use of the VFR applications first so that controllers will become comfortable with the use of CRDA in good weather conditions prior to operational use in IFR conditions.

2. If the CRDA is to be used for stagger operations in IFR conditions, the facility may want to consider phasing stagger operations into operational use by conducting some operations in VFR conditions first, and then proceeding to use in IFR conditions. This decision will depend on traffic demands on the facility and other factors. (Note: This was attempted at St. Louis, but led to intolerable arrival delays during VFR conditions.) It may be possible to provide the controllers with some CRDA staggering experience in VFR conditions by using the aid during non-peak arrival periods.

3. If the faci ·, intends to use the CRDA in the staggering mode of operation, it should consider the use of a monitor position during staggering operations for a period of time (to be determined by the facility) until sufficient experience is acquired with the aid. This recommendation is prompted by the higher-than-expected degree of speed control intervention by the local controller and the monitor controller during the evaluation at St. Louis.

4. For each application of the CRDA, maintain general logs regarding how much each application has been used by specific TRACON and tower crews, or by individual controllers. This will assist the transition in each case since TRACON and tower supervisors can provide on-the-floor assistance to less experienced controllers.

5. For IFR applications of the CRDA, apply the weather step-down criteria presented in the DCIA National Order in order to establish a comfort level with the user community and to give controllers experience in more tolerant weather conditions before stepping down to lower minima.

D. Operational Use

1. Design the CRDA controller procedures to closely mirror present procedures to the extent possible.

2. If operations at the facility can accommodate it, consider having all heavy aircraft use the same primary runway during stagger operations in order to reduce coordination. In this case, the controller that controls the heavy aircraft would then "follow himself", and the controller of the other approach would skip a slot after the ghost of a heavy.

3. To ensure maximum and most effective use of the CRDA, be sure that all TMCs and TSAs are aware of the importance of their roles in setting up the traffic flows when the decision is made to begin CRDA stagger operations, and for assisting with "exception handling" during stagger operations (e.g., handling of very slow aircraft). The need for real-time, dynamic decisions to set up or adjust traffic flows is essential to successful use of CRDA for stagger operations.

4. Clearly defined procedures should be established for coordinating the initiation and termination of CRDA-assisted operations (a) between tower controllers, (b) between TRACON controllers, and (c) between the tower and the TRACON.

5. If possible at the facility, the use of standard pullout procedures should be considered in order to simplify and improve the coordination between the tower and the TRACON.

6. After a period of initial operational use of each application of CRDA, controllers and supervisors should review the progress and problems associated with the use of that application of the CRDA in order to determine the conditions (traffic type, traffic flow, wind conditions, etc.) which are best suited to that application, and to identify conditions during which use of the CRDA application may need to be restricted or given special handling.

7. The impact of arrival staggering on departure operations should be analyzed by the facility at various step-down levels, especially at low visibility conditions. If excessive departure delays develop, then the facility should identify, evaluate and select a strategy that optimizes both arrival and departure throughput. Strategies to be considered by the facility might include: running a wider stagger, use of intersection departures, and building an occasional large stagger into the arrival stream and releasing departures in a "burst mode".

GLOSSARY

ACID	Aircraft Identification
ALPA	Airline Pilots Association
ARTS	Automated Radar Terminal System
ATA	Air Traffic Association
ATCT	Air Traffic Control Tower
ATC	Air Traffic Control
CAT	Category
CDR	Continuous Data Recording
CHI	Computer/Human Interface
CRDA	Converging Runway Display Aid
CTA	Computer Technology Associates
DBRITE	Digital Bright Radar Indicator Tower Equipment
DME	Distance Measurement Equipment
DCIA	Dependent Converging Instrument Approaches
EPS	Engineered Performance Standards
ETG	Enhanced Target Generator
FAA	Federal Aviation Administration
FAATC	FAA Technical Center
FAB	Facility Advisory Board
FMS	Flight Management System
FPL	Full Performance Level
FY	Fiscal Year
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
KIAS	Knots Indicated Airspeed
LC-N	Local Controller North
LC-3	Local Controller 3
NAS	National Airspace System
NBAA	National Business Airlines Association
NCP	NAS Change Proposal
NCTAM	Notice to Airmen
NATCA	National Air Traffic Controllers Association
NMI	Nautical Miles

OEP	Operational Evaluation Plan
ORR	Operational Readiness Review
PMR	Project Management Review
RAA	Regional Airlines Association
STL	St. Louis
TELECON	Telephone Conference
TMC	Traffic Management Coordinator
TSA	TRACON Supervisor for Arrivals
TWA	Trans World Airlines
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions